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FIRE SAFETY ANALYSIS OF THE POLAR ICEBREAKER REPLACEMENT DESIGN

VOLUME I

BY

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16. Abstract

This report documents the developmental application of the Ship Fire Safety Engineering Method (SFSEM) to the fire safety analysis of the Polar Icebreaker Replacement (PIR) design. The passive and active fire protection were analyzed in the integrated framework provided by SFSEM for every compartment on the PIR. Conventional fire protection engineering was employed whenever information necessary for SFSEM was not available. Recommendations for alternative solutions to fire safety discrepancies and guidelines for fire protection systems on the PIR are provided.

Five levels of fire protection were found in the PIR design. Passive fire protection is the most significant factor in meeting the fire safety objectives. The major improvement recommended for passive fire protection is to subdivide the boiler room. Refinements are recommended for Active Fire Protection systems but the most significant recommendation is for improved and integrated automatic fire detection. With these changes the fire safety of every compartment is well within the fire safety objectives established. Smoke control was identified as the area where the most significant gains could be made in fire protection and life safety.

The Ship Fire Safety Engineering Method proved to be an effective method for integrating the five levels of fire protection on the PIR. An extensive data base was developed which will greatly facilitate future ship fire safety analyses. Output from SFSEM would be very useful in damage control planning.

This report is presented in three volumes. Volume I presents the recommended improvements to the PIR and the analysis which lead to them. Volume II presents the data necessary to conduct the analysis, and Volume III presents fire safety summaries for each compartment and its barriers.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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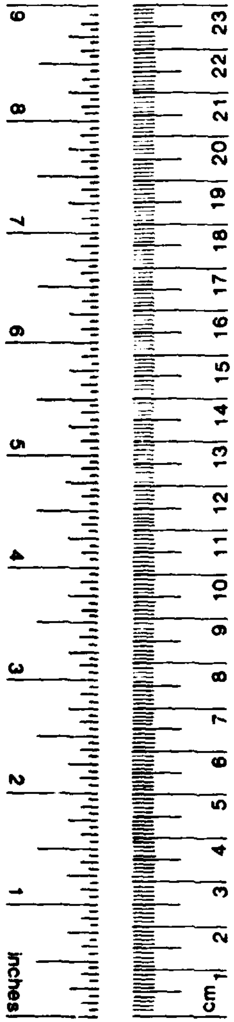
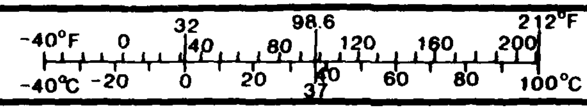


Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FIRE SAFETY ANALYSIS OF THE
POLAR ICEBREAKER REPLACEMENT DESIGN
VOLUME I

TABLE OF CONTENTS

		Page
1.0	**INTRODUCTION**	1-1
1.1	Objectives	1-1
1.2	Approach	1-1
2.0	**SUMMARY OF FIRE SAFETY DESIGN RECOMMENDATIONS**	2-1
2.1	Recommendations for Barriers on the PIR	2-1
2.2	Recommendations for Fire Protection Systems on the PIR	2-1
2.3	Recommendations by Compartment Types for the PIR	2-5
2.4	Other Recommendations for the PIR	2-7
2.5	Long-Term Ship Fire Safety Design Recommendations	2-8
2.6	Ship Fire Safety Engineering Method Recommendations	2-9
3.0	**FIRE SAFETY ANALYSIS BACKGROUND INFORMATION**	3-1
3.1	Overview of Ship Fire Safety Engineering Method	3-1
3.2	POLAR SEA and 270' CG Cutters	3-6
3.3	Timelines for Ship Fires	3-9
3.4	PIR Characteristics	3-10
4.0	**FIRE SAFETY OBJECTIVES FOR PIR**	4-1
5.0	**FIRE HAZARDS ON PIR**	5-1
5.1	Fire Frequency (Frequency of Established Burning)	5-1
5.2	Compartment Fuel Load	5-5
5.3	Probability of Self Limiting Flame (I value)	5-11
5.4	Pre-Flashover and Full Room Involvement (FRI) Time	5-17
5.5	Post-Flashover Rate of Heat Release	5-23
6.0	**BARRIERS ON THE PIR**	6-1
7.0	**ACTIVE FIRE PROTECTION ON PIR**	7-1
7.1	Fire Detection	7-4
7.1.1	Manual Fire Detection	7-5
7.1.2	Automatic - Fire Detection and Alarm Systems	7-6

TABLE OF CONTENTS

		Page
7.2	Automated and Manual Fire Suppression Systems	7-17
7.2.1	Remotely Controlled System Operation/Supervision	7-18
7.2.2	Seawater Pumping System	7-19
7.2.3	Seawater Fire Main	7-23
7.2.4	AFFF Proportioning Equipment	7-25
7.2.5	AFFF Fire Main	7-28
7.2.6	Seawater Hand Hose Lines	7-30
7.2.7	Seawater Sprinkler Systems	7-32
7.2.8	AFFF Hand Hose Lines	7-34
7.2.9	AFFF Sprinkler Systems	7-35
7.2.10	AFFF Monitor Nozzle	7-37
7.2.11	Halon 1301 Total Flooding System	7-39
7.3	Active Fire Safety Evaluations of Typical Compartments	7-41
7.3.1	Engine Room No. 1 (5-100-0-E)	7-42
7.3.2	Engineering Control Center (2-223-0-C)	7-52
7.3.3	Dry Laboratory (1-239-0-Q)	7-58
7.3.4	Science Storage - Aft Cargo Hold (3-311-0-AA)	7-63
7.3.5	Crew Berthing (2-121-4-L)	7-68
7.3.6	Arctic Gear Locker (1-307-2-A)	7-72
7.3.7	Ship Office (1-198-2-QO)	7-75
7.3.8	Helicopter Hangar (02-228-0-Q)	7-78
8.0	**FIRE SAFETY ANALYSES**	8-1
8.1	Flame Movement Analysis	8-1
8.1.1	Passive Fire Protection	8-3
8.1.2	Active Fire Protection	8-5
8.2	Smoke Movement Analysis	8-6
9.0	**CONCLUSIONS**	9-1
REFERENCES		R-1

LIST OF ILLUSTRATIONS

Figure		Page
3.1	Ship Fire Safety Engineering Method Diagram	3-2
3.2	Ship Applied Fire Engineering (SAFE) Functions	3-4
3.3	PIR Profiles	3-11
3.4	PIR Ships Plans (with Compartment Numbers)	3-15
5.1	Estimated Frequency of Established Burning (EB) for PIR	5-6
5.2	Estimated Fuel Load for PIR	5-12
5.3	Probability of Flame Limiting Itself for PIR Compartment	5-18
7.1	Automatic Detection Priority	7-7
9.1	Levels of Fire Protection on PIR	9-2

LIST OF TABLES

Table		Page
3.1	Deck Information for PIR	3-12
3.2	Compartment Use Information for PIR	3-14
4.1	Unacceptable Loss Definitions	4-2
5.1	Ships Considered in Fire Frequency Analysis	5-3
5.2	Fire Frequency Data	5-4
6.1	Barrier Materials and Properties	6-3
6.2	Door and Hatch Types	6-4
7.1	Active Fire Protection Systems	7-2
7.2	Estimated Fire Suppression Effectiveness - Engine Room No. 1	7-51
7.3	Estimated Fire Suppression Effectiveness - ECC	7-57
7.4	Estimated Fire Suppression Effectiveness - Dry Lab	7-62
7.5	Estimated Fire Suppression Effectiveness - Science Storage	7-67
7.6	Estimated Fire Suppression System Effectiveness - Crew Berthing	7-71
7.7	Estimated Fire Suppression System Effectiveness - Hangar	7-83
8.1	Flame Movement Results for Passive Fire Protection	8-3
8.2	Effects of Opening Accommodation Doors	8-4
8.3	Effects of Simulation Time	8-4
8.4	Flame Movement Results for Passive, Automated and Manual Fire Protection	8-5

FIRE SAFETY ANALYSIS OF THE
POLAR ICEBREAKER REPLACEMENT DESIGN
VOLUME II

TABLE OF CONTENTS

		Page
APPENDIX A -	Timelines for Ship Fires	A-1
APPENDIX B -	PIR Compartment Identification	B-1
APPENDIX C -	Compartment Hierarchy for PIR	C-1
APPENDIX D -	Fire Safety Objectives for PIR	D-1
APPENDIX E -	Fire Hazards for PIR	E-1
APPENDIX F -	Compartment Ventilation Factors on the PIR ..	F-1
APPENDIX G -	Calculation of Full Room Involvement Time ...	G-1
APPENDIX H -	Pre-Flashover Data and FRI Times for the PIR	H-1
APPENDIX I -	Fire Detection Priorities and Recommendations for the PIR	I-1
APPENDIX J -	Assigned Fire Protection Systems on the PIR .	J-1
APPENDIX K -	Effectiveness of Active Fire Protection on the PIR	K-1
APPENDIX L -	Flame Movement Analysis Results for the PIR .	L-1
APPENDIX M -	Smoke Movement for PIR Project	M-1

FIRE SAFETY ANALYSIS OF THE
POLAR ICEBREAKER REPLACEMENT DESIGN
VOLUME III

TABLE OF CONTENTS

		Page
APPENDIX N -	PIR Compartment and Barrier Fire Safety Summaries	N-1

1.0 INTRODUCTION

A project was assigned to the Marine Fire and Safety Research Staff for a comprehensive fire safety analysis of the Polar Icebreaker Replacement (PIR) design. The overall fire safety of a ship is not obvious. It is dependent on many factors, including the vast number of fire scenarios that are possible. What is required is a means to evaluate a ship for the many types of fire it may be subjected to. The analysis should be able to show what would happen if various alternatives such as protected cable trays, better fire boundaries, or improved fire detection had been used. In other words a means of simulating fires on ships is required which accounts for all of the relevant aspects in an integrated framework. The Ship Fire Safety Engineering Method (SFSEM) provides the basis for such a simulation. It was used to analyze the PIR.

A design for fire safety is reflected in the PIR Preliminary Design Report (1). This identifies the fire zone boundaries, stair towers, and barriers which, in conjunction with combustibles typically found in various compartments, comprise the major components of passive fire protection. The Preliminary Design Report also identifies the various fire protection systems planned for the PIR. These systems along with "standard practice" (2-12) for detecting, reporting and fighting fires comprise the major components of active fire protection. This project analyzed the passive and active fire protection in the integrated framework provided by SFSEM and then combined the results with the probability of having an unwanted fire to provide a measure of the overall fire protection for every compartment on the PIR.

1.1 OBJECTIVES

Conduct a complete fire safety analysis of the Polar Icebreaker Replacement design. Provide recommendations for alternative solutions to fire safety discrepancies and provide guidelines and/or performance requirements for the development of fire protection systems recommended.

Secondary Objective - Use the Ship Fire Safety Engineering Method (SFSEM) which is being developed to guide the Fire Safety Analysis to the extent practicable. During this process identify changes and improvements required to make the SFSEM a viable method for the fire safety design of Coast Guard cutters.

1.2 APPROACH

The SFSEM was used as the framework for the analysis. The Ship Applied Fire Engineering (SAFE) computer programming system was used to analyze the PIR fire safety on a compartment-by-compartment basis. Conventional fire protection engineering

techniques were employed wherever information necessary for SFSEM or SAFE was not available. A team approach was used to collect and analyze the voluminous data. Team members include:

> U.S. Coast Guard Naval Engineering Division and in particular Design Branch personnel who cooperated in a timely and professional manner to extensive detailed information requests. This included the locations of fire protection systems, ventilation plans, arrangements details, and materials which would be used in various places.
>
> Faculty and students at Worcester Polytechnic Institute. They provided expert assistance with the interpretation of SFSEM and performed specific portions of the analysis. The SFSEM is being developed in conjunction with WPI and is based on their engineering method for the fire safety of buildings.
>
> Rolf Jensen and Associates (fire protection engineering consultants) were contracted to perform specific tasks. In particular they analyzed individual systems for reliability and effectiveness.
>
> CompuCon was contracted to develop a data base for all PIR information, refine the SAFE simulation programs, enter data and run simulations.

The following individuals are acknowledged for their substantial contributions to the project and to this report: Prof. Craig Beyler, WPI; Prof. Robert Fitzgerald, WPI; Prof. Brian Savilonis, WPI; and Peter Yurkonis, Rolf Jensen and Associates.

2.0 SUMMARY OF FIRE SAFETY DESIGN RECOMMENDATIONS

This section presents the significant recommendations for improving the fire safety design of the PIR. In addition it presents recommendations which may be too involved to be included on the PIR but should be considered for ship designs in the future. The analysis of the PIR also served to identify areas in the SFSEM which need improvement. These are addressed in the last part of this section.

2.1 RECOMMENDATIONS FOR BARRIERS ON THE PIR

The barriers on the PIR are sufficient to meet the fire safety objectives. Fire Zone boundaries are adequately placed and have the proper fire resistance. Both of these results are based on the following assumptions:

All stair towers have self-closing steel joiner doors.

All elevators and dumb waiters have doors fitted which have fire resistance equivalent to steel joiner doors and that these doors are kept closed the majority of the time (i.e., when not in use).

All joiner bulkheads are carried completely to the overhead and penetrations are installed so that gaps do not exceed approximately 4 square inches. This assumption was made because the design does not call for false ceilings as found on many older ships.

These assumptions are critical to the fire safety of the PIR. Section 8.0 demonstrates that the passive component of fire protection produces the greatest benefit. These assumptions are central to passive fire safety. If the final design of the PIR does not require these steps, the fire safety should be reassessed.

Negligent hot work practices such as welding and brazing started some of the major fires listed in Navy Safety Center records. These fires often occur during yard availability periods when barriers are cut open and doors are held open. This severely impairs the passive fire safety of the ship. It is recommended that smoke curtains be used to segregate spaces in these situations. Testing at the Fire and Safety Test Detachment has demonstrated the effectiveness of these curtains in holding smoke back and reducing heat outside of the curtain.

2.2 RECOMMENDATIONS FOR FIRE PROTECTION SYSTEMS ON THE PIR

These recommendations are based on the detailed evaluations of the active fire protection systems proposed for the PIR and of

eight typical compartments. The detailed evaluations and, therefore, the justification for these recommendations can be found in Section 7.0 of this report.

AUTOMATIC - FIRE DETECTION AND ALARM SYSTEMS

Automatic fire detection is strongly recommended for the PIR. Early detection is essential for mission protection and life safety. It also provides increased response time which is valuable in limiting property damage. Section 7.1.2 gives specific recommendations for automatic fire detection on a compartment-by-compartment basis and provides a list of compartments prioritized by their need for fire detection. Section 7.3 provides estimates of detection time for the various detection types in eight typical compartments on the PIR. The fire safety simulations described in section 8.0 are only valid for the fire detection recommended in this report.

REMOTELY CONTROLLED SYSTEM OPERATION/SUPERVISION

1. Remote operating circuits, such as valve operation and pump start/stop circuits, should be Class "A" circuits. The circuits should transmit data-base commands rather than using operation of dry contacts for a command signal. This is to prevent change of status of the operated device in the event of circuit failure. For example, if a command were given to stop a fire pump by closing a set of normally open dry contacts, fire damage to that control circuit could cause a conductor-to-conductor short, giving the same stop command as closing the dry contacts. If a data base command is given, such a short would be seen as a trouble signal rather than as a stop command.

2. All remote operating circuits should be arranged so that loss of power to a circuit will not cause a change in status of the operated device nor prevent its being manually operated.

3. All operating circuits should be arranged so that attempted operation at two locations will not interfere with operation of the device. Such attempted operation at both the Engineering Control Center (ECC) and Damage Control Center (DCC) should not cause a loss of signal or a garbled signal to the device.

4. Status of all operated devices should be indicated at the remote operating panels in the ECC and DCC. Status indicating circuits can be Class "B" circuits, supervised with an end-of-line resistor, rather than Class "A" circuits. A break or open in such a circuit will cause a trouble signal, requiring circuit repair. It will not allow transmitting a signal over the break or open. If such a circuit is damaged during a fire, the operator in the ECC or DCC can still operate remote devices, but will not have verification of the device status.

SEA WATER PUMPING SYSTEM

1. Design the sea chest inlet to ensure a flooded suction to the fire pump without entry of surface debris or bottom sediment.

2. Use dual suction strainers in fire pump suction supply or provide a means to bypass the strainer so that the fire pump can remain in service while the strainer is being cleaned.

3. Operate each fire pump at a maximum flow condition on a regular basis to flush the discharge piping and fire main. This is to retard marine growth and corrosion. Provide access ports to inspect the interior condition of the fire pump piping and the related seawater fire main and AFFF fire main piping. Provide a fire flow meter in the fire main for use in testing the fire pumps to verify the pump output. Maintain a log of the pump output so that a decrease in performance can be identified and corrected.

4. Isolate the fire pump power supplies so that a single fire will not affect the power to more than one fire pump. Power should be maintained to at least two fire pumps at all times, particularly when in port or in a standby mode. If power is maintained to a single fire pump, and a fire occurs in the compartment in which the power supply or the fire pump is located, the fire protection water supply may be impaired.

5. Establish a fire pump operating procedure. Post that procedure at each fire pump operating station. The procedure should detail the steps to take in placing a fire pump in service and the decision process to select which of the three fire pumps is to be placed in service, based on the fire pump power supply availability and the fire location.

SEA WATER FIRE MAIN

1. Provide a jockey pump to maintain pressure on the fire main. Supervise the fire main water pressure to detect leaks, open valves, or breaks in the fire main. This is to ensure that the fire main is maintained in a tight condition, identifying leaks or failures prior to the need for using the fire main in an emergency condition. Maintaining pressure on the fire main should also reduce the possibility of water hammer when a fire pump starts, and reduce the possibility of trapped air entering the main, endangering fire fighters using hand hose lines.

2. Provide the fire flow meter and access ports discussed in section 7.2.3 to monitor the internal pipe condition.

3. Periodically flush the main and operate all valves through their full range of operation to ensure that they remain in an operable condition.

AFFF PROPORTIONING EQUIPMENT

1. Provide a fire main sectional valve between the two proportioner connections to the fire main. If this is done, loss of one section of the fire main would not take both proportioners out of service.

2. Arrange the power supply to the foam pumps and proportioning equipment control circuits in a fashion similar to that recommended for the fire pumps. Provide a backup power supply for each foam pump.

3. Establish an operating procedure for the foam system, similar to that recommended for the fire pumps.

4. Provide indication of foam proportioner pump and foam proportioner control valve status at both the ECC and DCC.

5. Increase the size of the proportioner and concentrate storage to handle the maximum flow demand if calculations show that the engine room demand is greater than that capable of being supplied by the currently specified proportioner.

6. Size the foam concentrate storage tank to ensure that the required amount of concentrate will be available during unstable ship conditions such as might be expected to occur during a heavy sea or icebreaking operations.

7. Provide dual strainers in the concentrate supply lines and in the seawater supply lines so that the system can remain in service during strainer cleaning.

8. Institute a routine maintenance program to inspect the foam proportioner for signs of corrosion or marine growth. If the foam proportioning equipment is operated, flush all of the lines in the proportioning equipment that carried seawater with fresh water to reduce the possibility of corrosion or marine growth.

AFFF FIRE MAIN

1. After each operation of the AFFF system, flush it and refill the fire main with fresh water. Maintain pressure on the main through a small jockey pump and monitor the main pressure at the ECC and DCC to verify the integrity of the main. This will help to reduce corrosion and marine growth on the valves, in the foam proportioner, and in the main. It will also provide assurance that the main will be serviceable when needed.

2. Operate all system control valves through a complete cycle on a regular basis, as with the control valves on the seawater fire main.

AFFF SPRINKLER SYSTEM

1. Establish a procedure for determining need to operate this system to ensure that it is not operated when other means of fire control could be effective with less total damage (fire damage, foam/seawater solution damage, recharge cost).

AFFF MONITOR NOZZLE

1. AFFF monitor nozzles do not appear to be an effective fire fighting tool for use in protecting this particular ship.

HALON 1301 TOTAL FLOODING SYSTEM

1. Because the Navy type CO_2 actuating system does not easily lend itself to supervision, it should be inspected on a regular basis as a part of the fire protection equipment maintenance program. A regular check should be made of each CO_2 firing cylinder, a visual check of all actuating system lines, and a visual inspection of all actuating system devices. The Halon system should be test fired with a dummy Halon system valve in place each time that the Halon cylinders are removed for servicing.

FIRE FIGHTING GEAR

The manual fire fighting gear was not analyzed in depth. A review of the Repair Locker Check List for USCGC POLAR SEA showed that it was adequate with the exception of fire fighter turnout gear. Fire fighting dress is merely the work uniform with long sleeves buttoned down, collar turned up and pants tucked into boots. Such poor outfitting endangers personnel in excess of the risks they already assume and it reduces their capability to perform an aggressive fire attack under the time and environmental constraints.

2.3 RECOMMENDATIONS BY COMPARTMENT TYPES FOR THE PIR

ENGINE ROOMS/MACHINERY SPACES

The potential for an oil spill fire should be evaluated along with measures which may control a fuel or lubricating oil spill. Such control devices could include:

1. Excess flow valves,
2. Restriction on pipe sizes,
3. Dual jacketed piping systems with drainage provided in the anular space between the inner and outer pipe,
4. Fusible link operated shutoff valves,
5. Remote valve operating mechanisms or remote control valves,
6. Isolating bulkheads to contain a potential oil spill.

The combined use of AFFF sprinkler systems and Halon 1301 total flooding systems may not be economically justified if other means are available to control the size or location of an oil spill.

The bundled electrical cables passing through these compartments should be separated by a physical barrier, particularly to prevent contamination of the cable surfaces by oily residue. A bundled cable fire will be difficult to control because of the cable location and the possibility of oily residue on the cable surfaces. An oil fire can cause significant damage to the exposed bundled cables in the compartment overhead as heat from that fire impinges on the compartment overhead.

A fire fighting procedure should be developed for using the installed systems in a logical manner. As discussed in Section 7.3.1, the portable fire fighting equipment should be used as the primary line of defense with the AFFF sprinklers or the Halon system being used as a secondary or tertiary line of defense, depending upon the fire situation. It is cheaper to recharge a portable fire extinguisher than it is to recharge an AFFF sprinkler system or a Halon 1301 total flooding system. If the portable fire extinguisher can work to put out the fire, it should be used in preference to a system which will cost significantly more to restore to service, thereby limiting the total damage caused by fire (direct fire damage, suppression agent damage, and suppression system recharge cost).

Horizontal access at the lowest level should be considered. This could be in the form of an automatically self-closing watertight door like those installed on the 270-foot cutters. This access would permit the fire fighters to approach the fire from the side or even from below which is significantly better than approaching the fire from above. This type of approach would also reduce the amount of smoke that would exit the fire compartment via the fire fighters path.

BOILER ROOM

The functions that the boilers provide were identified as critical while establishing the fire safety objectives. The design addresses this by specifying four boilers thus providing redundancy in supporting those functions. However, the original design received had all four boilers in the same boiler room. A fire in that compartment would threaten the entire ship's capability to perform these critical functions. Based on discussions with the designers we understand that this compartment will be subdivided into two compartments with two boilers in each. This analysis assumes this to be the case and that the dividing bulkhead provides fire resistance similar to a steel joiner bulkhead.

ENGINEERING CONTROL CENTER

This compartment is critical because it houses the main propulsion and ship service electrical power distribution busses. It is the critical link between redundant engine rooms and main motors. The fire protection for this compartment should be designed to prevent the loss of all buss transfer capability from any single fire. A subdivision and physical separation of the busses would greatly assist this objective.

CARGO HOLDS AND STORAGE SPACES

For cargo holds and storage spaces protected by sprinkler systems cargo must not be stacked to the overhead. The cargo must be kept at least 18 inches below the sprinklers to allow proper water distribution from them.

HELICOPTER HANGAR

1. A fixed temperature detection system is recommended to avoid potential false alarm problems with other types of detection.

2. Establish a fire attack plan for the two types of fires expected in this compartment. Use the hand hose lines in conjunction with the AFFF sprinkler system in affecting control of both a flammable liquid spill fire or a stored cargo fire.

3. Provide a drainage system to control the sprinkler system discharge water so that the discharge water and spilled fuel is not allowed to enter the interior of the ship on lower levels.

2.4 OTHER RECOMMENDATIONS FOR THE PIR

The smoke movement analysis shows the rapidity with which smoke travels vertically. This indicates that access to hatches must be controlled quickly. It reconfirms that doors leading to stair towers should be the automatic self-closing type. Compartments with heavy fuel loads should have dampers that can be closed remotely, possibly from the bridge or ECC when fire is detected.

One technique that should be considered for the PIR is pressurization of passageways. This would eliminate or minimize smoke in escape routes and would provide better access for fire fighters.

Non-heat generating data transmission lines should be separated from power carrying cables and wrapped with fire retardant insulation. Fires which affect these lines can cause significant impact on ship operations and control functions thus reducing mission capability. Separation of such cables would improve survivability.

The practice of allowing passage of vital or hazardous utilities through accessways and vital spaces should be given careful review. Use of passages and accessways to house hazardous utilities may compromise their fitness during fire fighting operations.

The lead PIR should be reanalyzed in the as-built configuration so that the data base can be updated and the fire safety level established. This would establish a base which could be referred to during any modifications or rehabilitations.

2.5 LONG-TERM SHIP FIRE SAFETY DESIGN RECOMMENDATIONS

Smoke control is the area where the most significant gains in fire safety can be made. While refinements can be made, passive and active fire safety are generally well addressed in Coast Guard Cutter design. Smoke control on the other hand has not been addressed. This should be given considerable attention and incorporated in future cutter designs.

A subset of the above recommendation is that Engineering Control Centers should be located in a different ventilation zone than machinery spaces. The ECC houses most of the controls for shutting down the engines, starting fire pumps, stopping fuel flow, etc. If it is inundated with smoke from a machinery space fire then these functions may not be accomplished and the fire will become worse.

Development of a compartment hierarchy for each class of ship based on missions and functions would aid in developing fire protection alternatives on a rational basis. It would also be useful for other purposes such as the routing of cables and utilities. Section 4.0 provides an approach to developing such a hierarchy.

This was the first time that compartment-by-compartment fire safety objectives were established for a Coast Guard Cutter. Working without precedent resulted in objectives which may be too lenient. The method for determining these objectives should be refined and then validated against operational cutters. This will result in future users having more confidence and eventually give engineering management the tool they need for assigning the fire safety they desire and can afford.

Cable runs should be considered early and carefully in the design stage. They are one of the principal routes of fire spread. To prevent this they should be isolated. They are also vulnerable to damage from a fire in a compartment they transit. Depending on what functions the cables serve, this can have debilitating effects. To prevent this they need to be protected from fire. Early consideration should balance isolated routing and fire protection with the criticality of the functions they serve.

Installations of fresh water, fast action "on-off" sprinklers should be considered. A fresh water system of this type would conserve water, reduce water damage, and reduce flooding and spread of flammable liquids through overflow. It can provide a high fire extinguishment capability at lower cost than more complex systems such as Halon. Also water is not a threat to the upper atmosphere such as Halon. Reliability of these systems is not well established and therefore the systems should be considered carefully.

2.6 SHIP FIRE SAFETY ENGINEERING METHOD RECOMMENDATIONS

The smoke movement analysis methodology needs to be improved. Smoke movement through ducting as well as doors and passageways must be addressed. The resultant method should be able to work from the data collected for the flame movement analysis. Such a method will be essential to the proper design of smoke control systems.

The method for determining the fire detection priority of each compartment as presented in Section 7.1.2 needs to be refined and validated.

Currently the SAFE programs determine heat energy impact on barriers based on Inberg's theories of equal areas under time temperature curves produce equal fire impacts. Recent work has shown that the normalized heat load concept provides a significantly more accurate heat energy impact. This concept should be worked into the SAFE programs.

An attempt to deterministically calculate the full room involvement time was made as part of this project. It did not work very well and so these times were assigned by engineering judgement. This should be readdressed and corrected for future utility of the SAFE programs.

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3.0 FIRE SAFETY ANALYSIS BACKGROUND INFORMATION

In order to conduct a thorough fire safety analysis, the analyst must mix both theory and experience. This section will briefly describe the theories developed and used as well as the sources which were investigated to provide relevant experience for the fire safety analysis of the PIR.

3.1 OVERVIEW OF SHIP FIRE SAFETY ENGINEERING METHOD

The Ship Fire Safety Engineering Method (SFSEM) for fire safety analysis evaluates the probability of spaces and barriers successfully limiting a fire on a compartment-by-compartment basis. The evaluation incorporates fire growth hazard potential, automated and manual suppression, and barriers. The system is structured in a manner that allows probable paths of fire propagation to be simulated. When time is incorporated, the simulation calculates the probable paths based on time durations.

At a gross level a SFSEM analysis follows the logic presented by the bubbles on the right side of Figure 3.1. A compartment starts at Fire Free Status (FFS). From this point there is some probability that an Ignition (IG) will occur. If an ignition does not occur (IGbar - note; A bar over any symbol signifies "not") then the probability of fire is Limited (L_n) to the first room (i.e., n=1). When an ignition does occur the fire will have a probability of either reaching Established Burning (EB = a fire size of approximately one square foot which is taken to be the design starter fire) or not reaching it (EBbar). If it does not, then the fire is again limited to the first room L_1. Once the fire reaches EB it is assumed to progress to full room involvement as long as there is sufficient fuel in the compartment, heat is not removed too rapidly, and the fire is not limited by I, A, or M.

I designates the probability that the fire will terminate itself. If it does not (I bar) then there is a probability that the fire will be limited by Automated (A) fire extinguishing systems. If they do not (Abar) limit the fire then there is a probability that the fire will be limited by Manual (M) fire fighting efforts. If the fire fighters do not (Mbar) limit the fire in the compartment of origin, then the fire will attack the barriers of that compartment.

There are three possible outcomes when a barrier is attacked by fire. The barrier may limit (B_{1-2}) further spread of the fire. The barrier may fail by passing enough heat into the next compartment to start another EB. This is called a Thermal failure and referred to as Tbar. Or the barrier may fail through a massive break thus passing heat, fire and smoke into the next compartment. This is called a Durability failure and referred to as Dbar. The Dbar and Tbar failure modes result in different

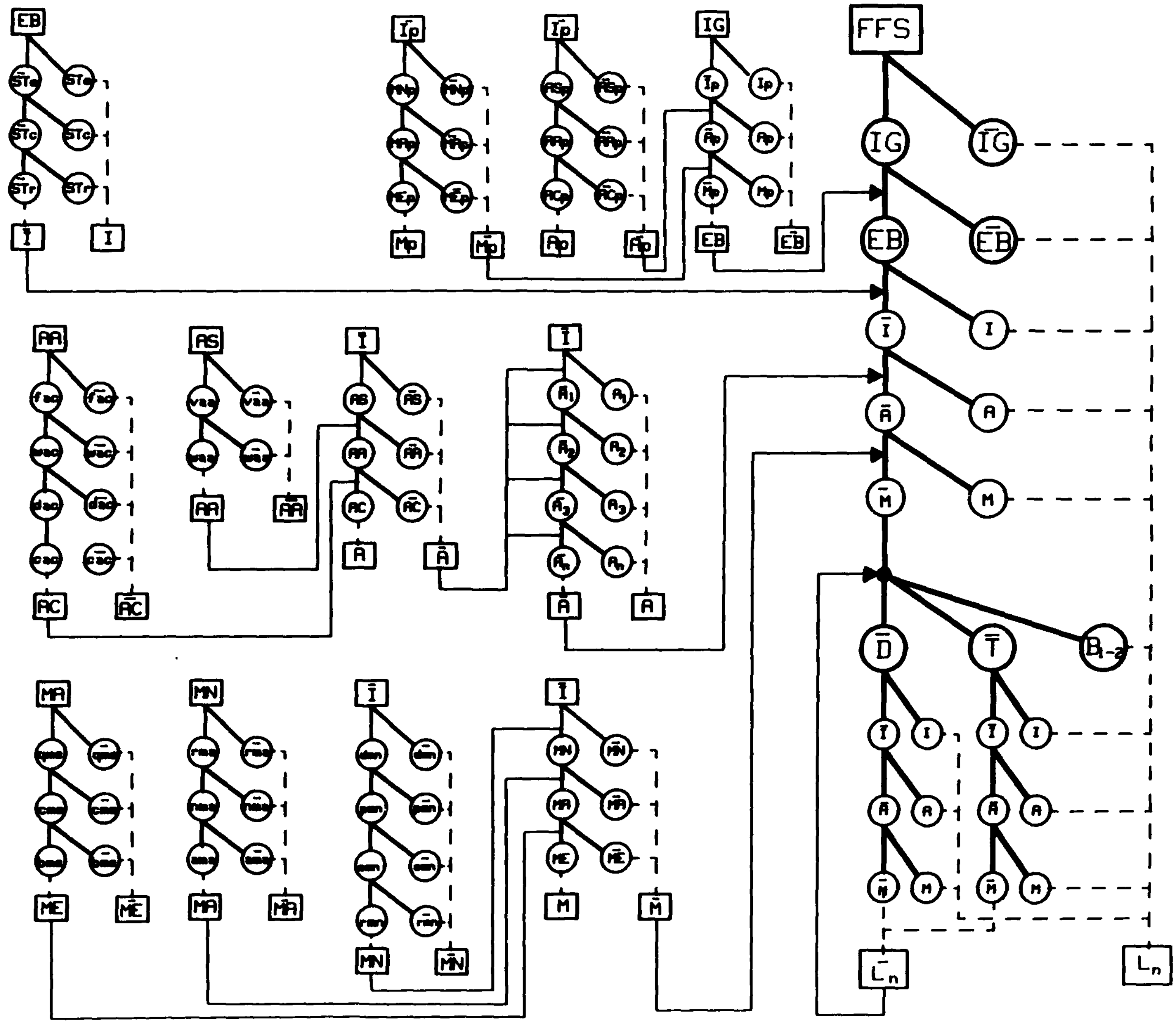


FIGURE 3.1 SHIP FIRE SAFETY ENGINEERING METHOD DIAGRAM

fire impacts in the adjoining compartment. It is clear that the resultant fires will be different which in turn results in different probabilities for I, A and M in each case. These are evaluated separately and combined to result in the probability that fire will be limited in the second room L_2. If it is not (L_2bar) then it will attack the next barrier and continue through the Dbar-Tbar-I-A-M loops until there is a probability of 1 that it is limited in compartment L_n.

The summary level of the SFSEM was presented above. The "bubbles" on the left two thirds of the figure identify the many details which must be aggregated to provide the proper input to the summary level bubbles on the right side. These detailed bubbles will be the subject of a future paper completely describing the SFSEM. Suffice it to say that the details were considered in the PIR fire safety analysis.

SHIP APPLIED FIRE ENGINEERING PROGRAMS

The Ship Applied Fire Engineering (SAFE) computer programs that help automate portions of the SFSEM are actually an integrated series that requires engineering evaluations, ship geometry, and ship features as input. They enable a person to describe the layout of a ship, enter data values for compartments and barriers, and run fire simulations for the ship. These data values as well as results of the simulation can be output in numerical or graphical form. Each major component of the programming system depicted in Figure 3.2 is described below.

Describe Initial Design

Before a simulation can be run, information about the layout of the ship must be provided. The coordinates of the corner points for each compartment are entered into a database. This information is used by a program which establishes room-to-room connectivity and calculates the location and area of all barriers in the ship. This barrier information is written to the database, providing a permanent record of the connections between compartments. Identifying all of the barriers for a compartment is important to ensure that the simulation includes all possible paths of fire propagation.

Accommodate Design Changes

If changes are made to the design of the ship, the coordinates are updated and the connectivity is regenerated to provide the most current information for simulations and for use by the engineer in analyzing output.

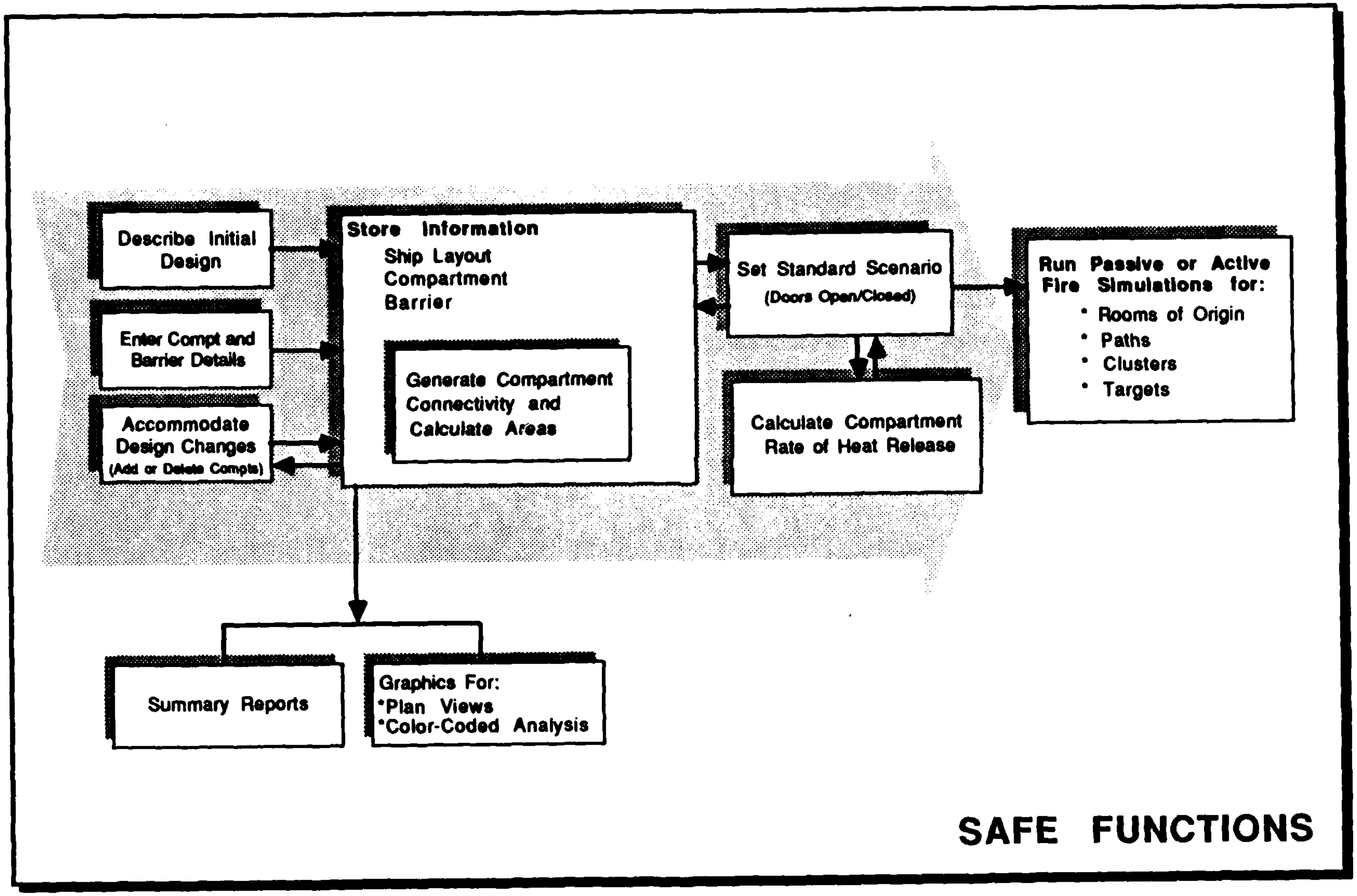


FIGURE 3.2. SHIP APPLIED FIRE ENGINEERING (SAFE) FUNCTIONS

Enter Barrier and Compartment Details

The final step in preparation for analysis is the input of data values for each compartment and barrier. Each compartment must be evaluated to determine data values for the critical variables that affect fire growth in the compartment. These values were established for the PIR by the engineering evaluations described in Sections 4.0 through 7.0 of this report.

Select Output Options

After all information has been entered into the database, various options exist to utilize this information:

1. Print SUMMARY REPORTS which allow the engineer to check validity and consistency of information input as well as aid in the analysis.

2. Develop GRAPHICS for plan views to be used as a reference or color-coded analysis to clearly depict problem areas in the ship based on barrier strength, compartment fuel load, etc.

3. Run FIRE SIMULATIONS on the entire ship or portions of it.

Run Passive or Active Fire Simulations

A fire simulation consists of starting a fire at time 0 in one or more compartments (referred to as rooms of origin) and allowing it to progress through time to a predetermined stopping point. Fire simulations can be run showing the frequency of involvement of a compartment or probable paths of fire propagation. The user must specify the conditions of the simulation. These specifications include the scenario to be used as input to the simulation, the compartment(s) in which the fire starts, the duration of the simulation, the data values that are desired as output, and the simulation times at which values will be provided. Various scenarios are used to create data files with differing types and numbers of doors and hatches open. This is a vital factor in calculating a compartment's rate of heat release as well as a barrier's fire resistance.

The simulation begins by starting a fire in the room(s) of origin specified by the user. After full room involvement in these room(s) of origin have been reached, the simulation calculates the quantity of heat energy attacking each barrier up to the barrier's failure. The cumulative heat energy impact is compared to the fire resistance of the barriers; the probability of barrier penetration is determined. If the fire has penetrated a barrier, the simulation starts another established burning in the next compartment.

Zero strength barriers (i.e., barriers which have been inserted for convenience to subdivide a compartment) are treated specially. Fires are started in the compartment of origin and the compartment separated by a zero strength barrier at the same time. From that point they progress according to the individual compartment's fuel loads and other characteristics.

In this space-barrier propagation, the simulation builds a set of paths of fire spread. As the simulation progresses, more and more rooms may become involved in the fire, producing more paths. The number of paths of fire spread grows exponentially over time. When the simulation reaches a condition at which the user requested output, the values of variables describing the probable extent of the fire for each path are calculated and provided.

The computer simulations performed by SAFE permit a variety of alternatives to be studied. The user can request the following types of information:

a. Details of all paths produced from one simulation.

b. Results of multiple simulations run with each compartment on the ship used as a room of origin. This information includes listings of:

- -room of origin barriers that fail in a given time,
- -"clusters" of contiguous rooms involved in a fire from each room of origin, or
- -the relative frequency of failure of each compartment as a target for fires started in all rooms of origin.

Analyzing the SAFE Results

By using the options mentioned above (Summary Reports, Graphics, and Fire Simulations), the engineer can gain an insight into the complete fire safety system for the ship.

3.2 POLAR SEA and 270' CG CUTTERS

Ship checks were made of the USCGC POLAR SEA (9-11 November 1986) and a few 270' cutters under construction in Newport, Rhode Island (12 February 1987). These checks were made to obtain first-hand information on ship characteristics necessary for SFSEM. The POLAR SEA was chosen to provide information peculiar to an icebreaker. The 270's were chosen to provide information on the newest forms of construction, fire protection systems, and accommodation materials. These will be the closest to what would be specified for the PIR.

During the visit to the POLAR SEA a fire drill was conducted to provide specific information for analysis of the PIR. The results of that drill are presented on the following pages.

FIRE DRILL ON USCGC POLAR SEA
11 November 1986

PURPOSE:

Conduct a fire drill to determine the response times for manual fire fighting teams under operating conditions on a Coast Guard icebreaker.

SCENARIO:

A lube oil spray fire was simulated in Diesel Engine Room #1, port side aft. This was accomplished by putting smoke to a detector in that space and notifying investigators as they reached the top of the ladder that "there is so much smoke coming out of this space that you cannot enter without equipment."

LIMITATIONS:

- The fire drill had to be announced as a drill which tends to reduce the confusion factor and eliminates panic.
- No smoke was used in the simulation and lighting was not turned off. Thus fire fighting personnel could proceed with good visibility.
- The USCG POLAR SEA had recently returned from refresher training where they had received excellent marks. Thus they were well trained for this type of drill.

These three points would cause the response times to be faster than would normally be expected. This could be considered a "best case" situation.

- Many functions are performed by several people over a short period of time in the Engineering Control Center. The observers who recorded times were not completely familiar with all of the functions. Therefore, some of the times recorded in ECC may contain some inaccuracies.

RESULTS:

Activity	Time	Reporter
Scene leader on watch	00:00	ECC
Smoke to detector	00:00	Aux. 1
Fire alarm in ECC	00:01	ECC
Investigator left ECC	00:11	ECC

Activity	Time	Reporter
Scene leader and 2 Aux. 1 men went up ST 3-143-1-L to 2nd deck to ST 2-76-1-L. Scene leader stopped at stairwell. Two Aux. 1 men investigated fire in Diesel 1. (Not normal; should leave after report.)	00:11	Aux. 1 Diesel 1
Aux. 1 watch shouted to DCC PARDI at top of ST-2-76-1-L. Scene leader started foam hose station 2-119-1-E. Turned over to Machinery personnel. 200' hose + 100' SW hose added. Hose down to ST 2-76-1L.	00:29±	Aux. 1
ECC investigator arrives Aux. 1.	00:50	Aux. 1
ECC investigator called in fire to ECC.	00:55	Aux. 1
Fire called in to bridge.	01:13	ECC
Fire announced over ship's PA system.	01:59	Bridge
DCC to Mech Foam Station	02:25	ECC
Scene leader assigned foam station to machinery personnel. Took nozzle to ST 2-76-1-L and gave it to arriving OBA men.	02:29±	Aux. 1
Investigator left Repair 2	03:31	DCC
Investigator left Repair 3	03:92	DCC
Scene leader went down ST 2-76-1-L and started foam line at 3-77-1-L. Aux. 1 watchmen attached SW hose line and applicator to cool door ST 3-128-1-L.	03:44±	
Cooling door to Mach Space and deck.	03:59	Aux. 1
Mechanically isolated Diesel 1	04:59	ECC
Fire pumps on line	05:51	DCC
2 OBA men - 2 foam hoses arrive Aux. 1. Do not enter until backup men arrive.	06:25	Aux. 1
Ventilation Fans secured in fire space. Diesel 2, turbine and other spaces secured.	06:27	ECC
Load shifted from Diesel 1 and Electrical Isolation (sim) of Diesel 1 ordered.	07:29	ECC

Activity	Time	Reporter
Entered Diesel 1. 2 men/hose - 2 hoses - AFFF	07:30	Aux. 1
1st deck foam hose first into ST 3-128-1-2 with OBA men.	07:30	
2nd deck foam hose second into ST-128-1-L with OBA men.	07:31	
Zebra Set Bridge	08:22	DCC
Electric isolation of Diesel 1 (sim) completed.	08:29	ECC
Repair 2 and 3 comming. 12 OBA men, many support personnel.	09:29	
Hose Line at Fire	09:39	Aux. 1
Zebra Set - Repair 3	10:09	DCC
Zebra Set Engr - Level	10:24	DCC
Fire Under Control	10:49	DCC
Helo foam staffed	11:49	DCC
Zebra Set - Repair 2. Set sooner than reported	13:03	DCC
Fire out	14:09	DCC
Vent and cleanup, Diesel 2	15:19	DCC

3.3 TIMELINES FOR SHIP FIRES

To develop further information on the timing of fire growth and of fire fighting efforts, timelines for ship fires were developed from data available in accident reports. Timelines briefly describe the type of fire, its origin and cause when known. They then attempt to assign a time (and answer questions) when each of the following events occurred:

Start of fire (EB time) taken as time 00:00
Fire detected (manual or automatic detection?)
Fire announced over ship's communications
Automated fire protection system used (what kind?)
Fire party outside compartment on fire
Fire party applying agent to fire (type of agent?)
Significant fire fighting events (describe)
Fire under control
Fire extinguished

Timelines were developed for thirty-five Coast Guard Cutter fires, a fire on the SCANDINAVIAN SEA, a fire on the SCANDINAVIAN SUN, and six ships lounge burnout experimental fires (see Appendix A, TIMELINES). The information developed was used as a basis for estimating A and M values for various compartments and scenarios on the PIR. A few things reoccurred often and, therefore, bear reporting as lessons learned.

LESSONS LEARNED FROM TIMELINES

Fuel and lubrication oil lines play a significant role in ship fires. Seven reports dealt with fires or explosions caused by these lines. In a CGC CHASE fire (Rpt. # 001056) a 3/8" copper pressurized lubricating oil supply line failed creating an oil spray fire. In the SCANDINAVIAN SUN fire (Rpt. # 001040) a hole in an oil line fueled the fire when a 1/2" threaded elbow came loose. In a CGC JARVIS fire (Rpt. # 001230) a small hole developed in a 1/4" copper fuel gauge line creating a spray fire. In a CGC MOHICAN fire (Rpt. # 001221) a broken fuel line caused by insufficient lagging resulted in the fire. In a CGC SHERMAN fire (Rpt. # 001251) broken fuel and lubrication oil lines caused by an explosion resulted in fuel being added to the fire. In a CGC JARVIS fire (Rpt. # 001229) copper tubing chafing from vibration ruptured and fueled the fire. In a CGC DORADO fire (Rpt. # 001216) vibration caused a threaded fitting on a lube oil line to come loose thus fueling the fire.

In one incident (CGC MOHICAN - Rpt. # 001221), PVC fumes became so intense that fire fighting was hampered. The toxic fumes prevented entry into the compartment for securing engines. All personnel in the interior of the ship were forced outside within 20 minutes of the start of the fire. In another (CGC DURABLE - RPT. # 001219) an excess of toxic fumes were produced through the burning of polyurethane, neoprene, and PVC, which made fire fighting more difficult.

There were also problems with PKP extinguishers. The powder in these extinguishers seems to pack down from the vibration of the ship. This problem can be noted in casualty reports on the CGC JARVIS (Rpt. # 001222), the CGC MOHICAN (Rpt. # 001221), and the SCANDINAVIAN SEA (Rpt. # 001253).

3.4 PIR CHARACTERISTICS

The Preliminary Design of the PIR calls for a 460-foot vessel having nine decks and 405 compartments. Its general shape can be seen in Figure 3.3. The decks and the number of compartments on each are summarized in Table 3.1. The compartment names, numbering and locations were obtained from general arrangement drawings dated 1/29/87 and later updated from drawings dated 5/12/87. Lists of the compartments sorted in different ways were created to facilitate cross referencing. Compartments sorted by

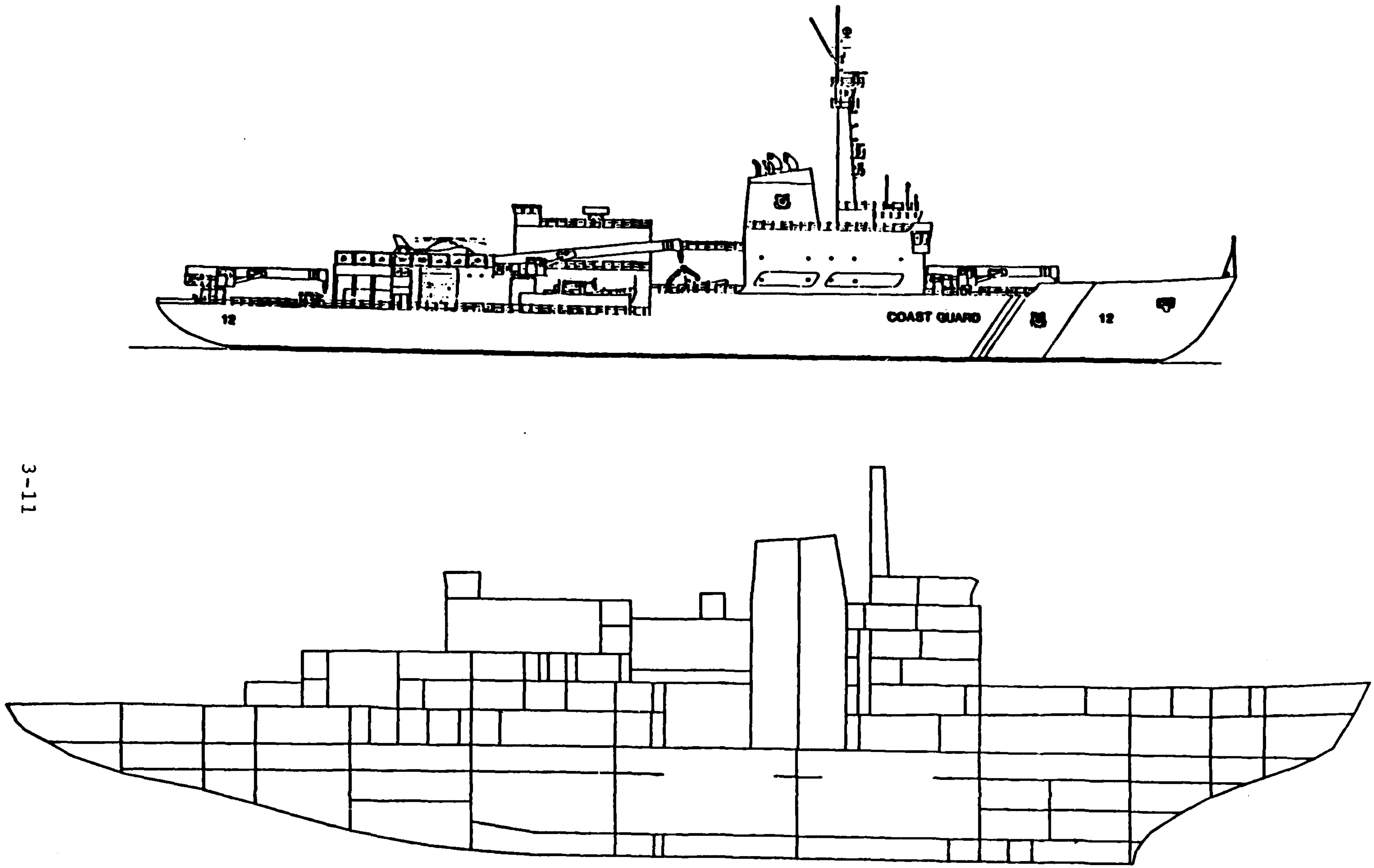


FIGURE 3.3. PIR PROFILES

TABLE 3.1

DECK INFORMATION
for
POLAR ICEBREAKER REPLACEMENT
(drawings dated 05/12/1987)

deck.out
02/24/1988 15:24:05
Page # 1

DECK NO.	DECK NAME	HEIGHT (ft)	# COMPART
04	04 LEVEL	9.00	7
03	03 LEVEL	9.00	22
02	02 LEVEL	9.00	42
01	01 LEVEL	10.00	80
1	MAIN DECK	13.00	93
2	SECOND DECK	9.00	89
3	THIRD DECK	10.00	28
4	FIRST PLATFORM	10.00	26
5	TANK TOPS	8.00	15
		TOTAL	402

name, by compartment number, and grouped by use indicator where each group is sorted by compartment number are presented in Appendix B. The number of compartments associated with each use indicator are presented in Table 3.2.

The general arrangements were entered in the SAFE programming system as shown in Figure 3.4. A few long and complicated passageways were subdivided on entry so that the connectivity algorithm in SAFE could handle them. The created spaces were divided by "zero strength" barriers so that they were handled properly in the simulations. Compartments which span multiple decks (i.e., Engine Rooms, Boiler Rooms, Motor Room, Auxiliary Generator Room, Vestibule and Hangar) were subdivided at each deck level by a "zero strength barrier." For example, Engine Room No. 1 is entered into the SAFE programming system as compartments 3-100-0, 4-100-0 and 5-100-0.

TABLE 3.2

COMPARTMENT USE INFORMATION
for
POLAR ICEBREAKER REPLACEMENT
(drawings dated 05/12/1987)

use_id.out
02/01/1989 10:19:53
Page # 1

ID	#cmpts	Use description
AA	3	Cargo Holds
AG	22	Small Storage Spaces -- Gear Lockers
AR	5	Refrigerated Storage Spaces
AS	25	Storerooms
C	6	Ship and fire control operating areas normally occupied.
E	22	Machinery areas which are normally occupied.
F	35	Fuel oil, diesel oil fuel, & lubricating oil tanks
J	6	JP-5 tanks
K	2	Stowage of chemicals/dangerous materials; not gas and oil
L	6	Living quarters/medical/dental areas
L1	10	Berthing Space for 1
L10	7	Berthing Space for 10
L2	26	Berthing Space for 2
L4	2	Berthing Space for 4
L6	4	Berthing Space for 6
L8	1	Berthing Space for 8
LL	6	Lounge areas
LP	31	Passageways
LW	54	Wash room, water closet and shower areas
M	2	Ammunition (stowages and handling)
Q	36	Areas usually unoccupied: engineering, electronics, galleys
QF	5	Fan Rooms
QO	16	Offices
QS	9	Scientific Spaces
T	10	Elevators, dumb waiters
TS	24	Staircases
TU	12	Uptakes
V	6	Void Cmpts./cofferdam, ballast wing tanks, void wing tanks
W	9	Cmpts. storing water, bilge, sump, and peak tanks
--	----	
29	402	

Figure 3.4 (1 of 3 pages)
Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Fri Jul 10 10:05:37 1987

04 LEVEL

03 LEVEL

02 LEVEL

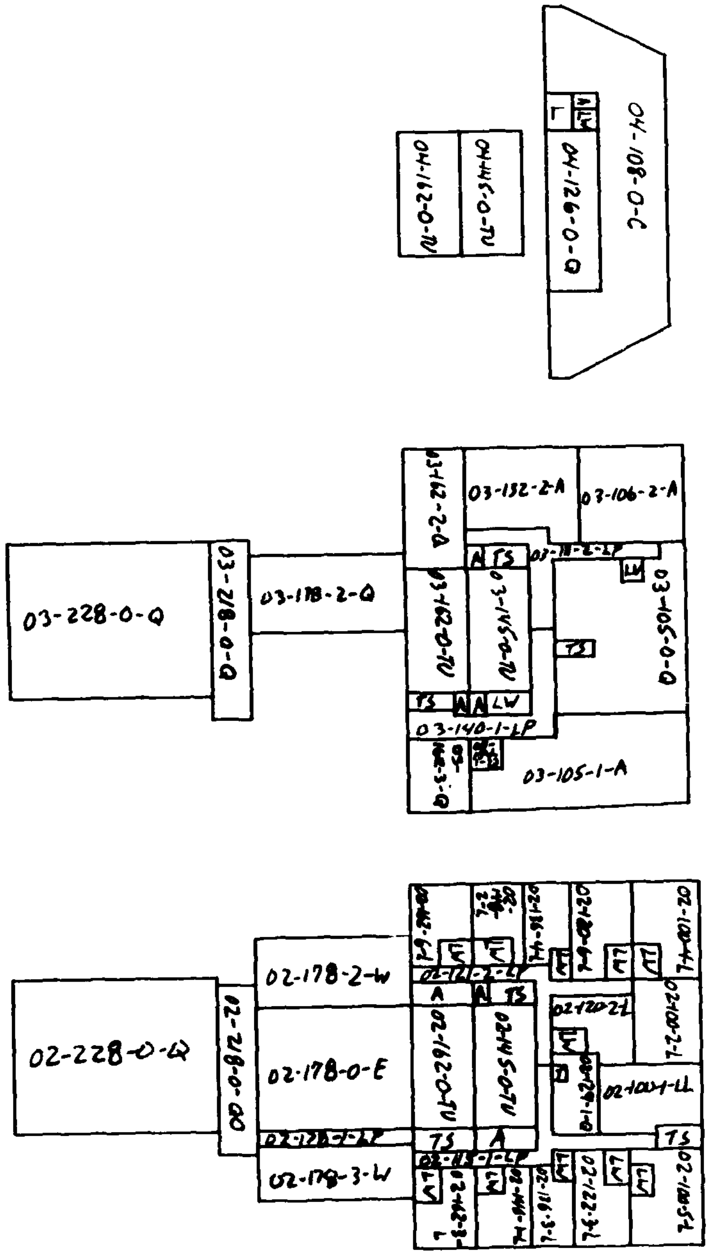


Figure 3.4 (2 of 3 pages)

Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Mon Jun 29 08:43:20 1987

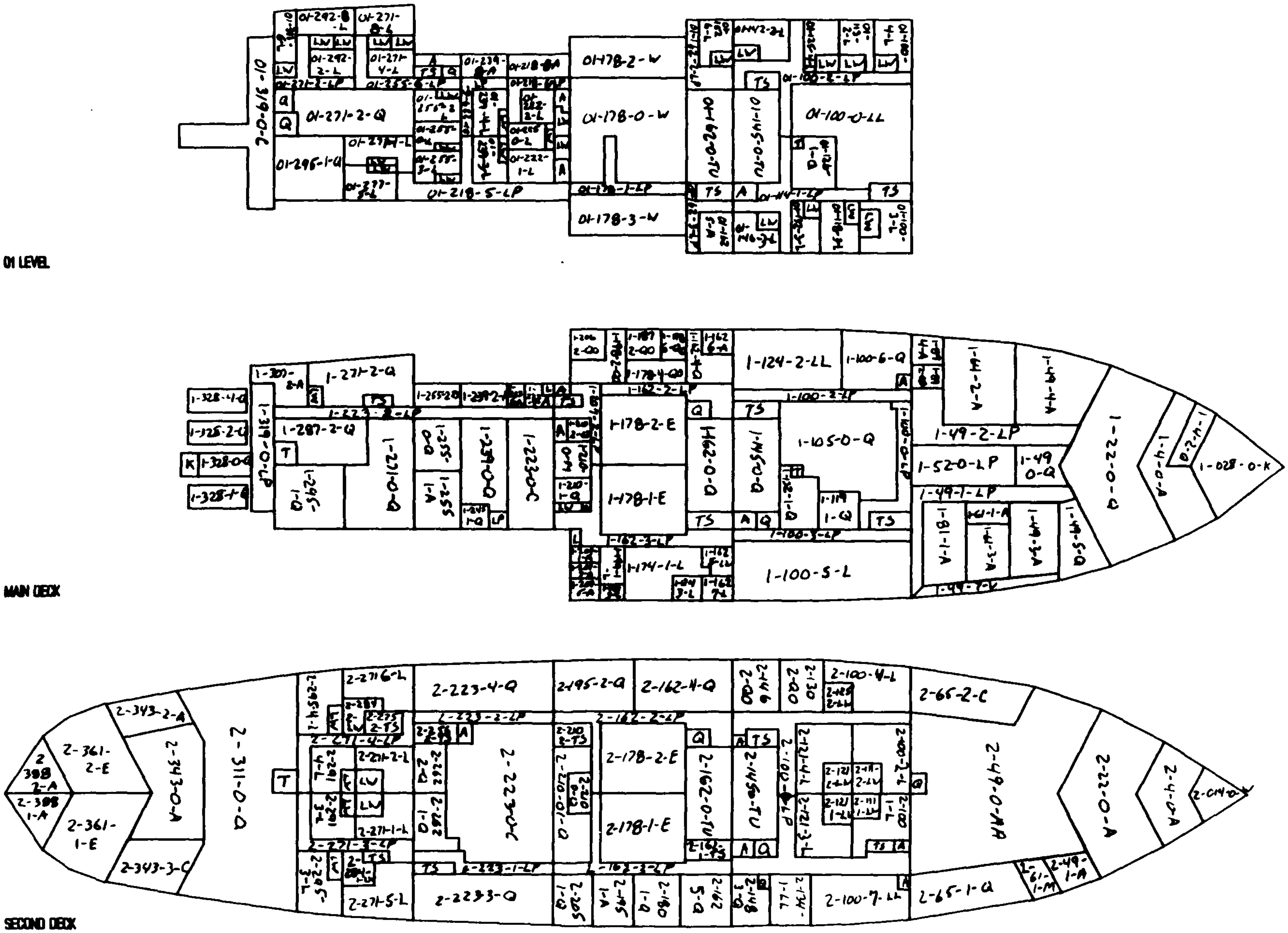
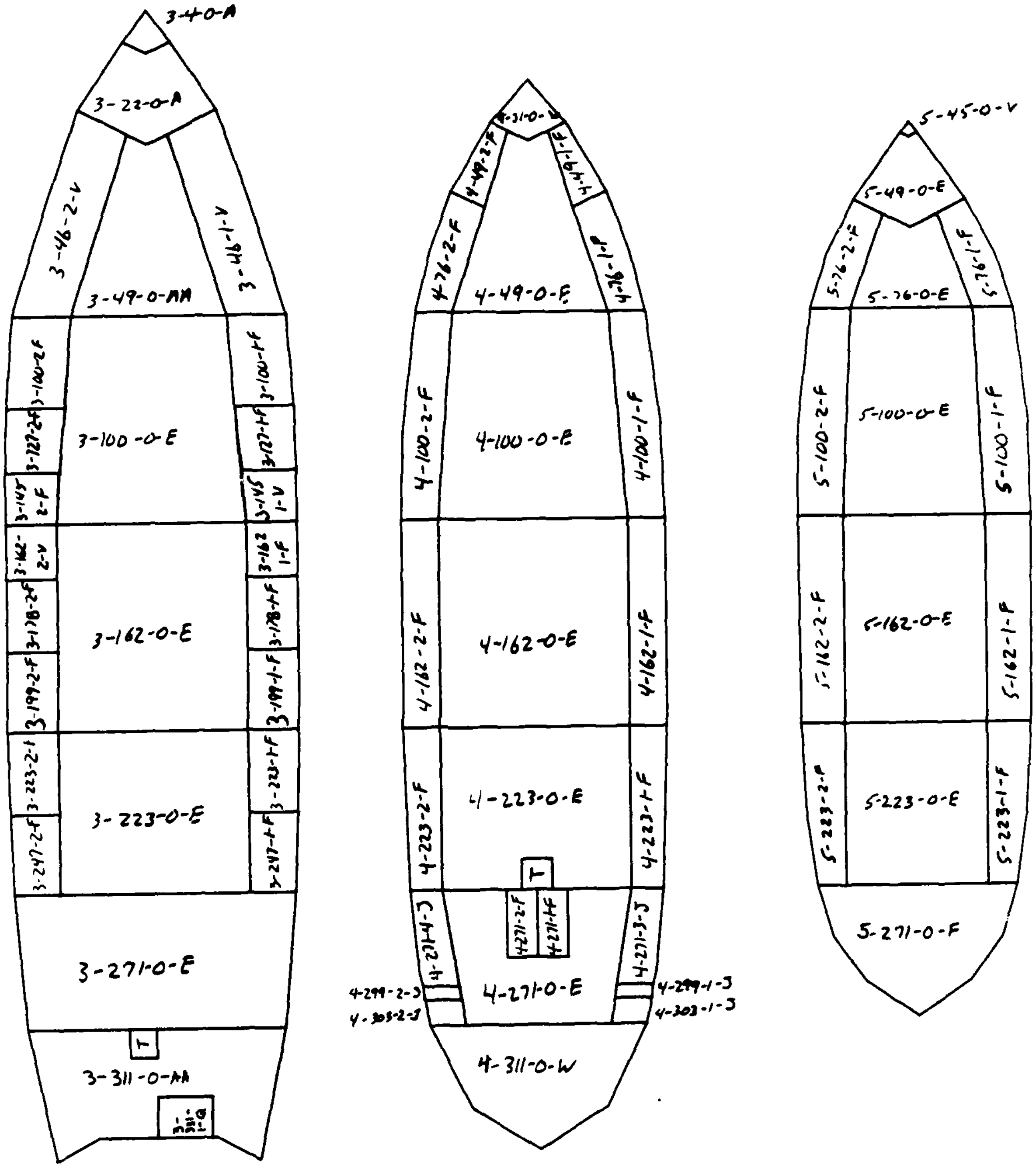


Figure 3.4 (3 of 3 pages)
Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Mon Jun 28 08:43:20 1987



THIRD DECK

FIRST PLATFORM

TANK TOPS

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4.0 FIRE SAFETY OBJECTIVES FOR PIR

In order to use any performance-based engineering method, performance objectives must be developed. For the fire performance of compartments on a ship this should be done by developing a compartment hierarchy based on the mission essentiality of each compartment. A compartment would be considered essential because of functions performed in it or because it contained systems, or system components, essential to ship functions. Fire safety objectives would follow from this hierarchy directly.

A complete development of the compartment hierarchy snould include the identification and ranking of the ship's missions, the functions required to conduct the missions, the systems necessary to perform the functions, the subsystems which support the systems, and the umbilicals that feed them. When these are all identified and traced, the compartments which house any must be catalogued. The hierarchy would then be developed in the order of the compartments which contained the largest number and most critical functions, systems, subsystems, etc. This task was beyond the scope of this analysis. In its place, fire safety objectives were developed in concert with the ship designers as reported below. A compartment hierarchy was implied by these objectives and is presented in Appendix C. A method for the development of a ship compartment hierarchy based on mission essentiality was developed and will be reported on separately.

UNACCEPTABLE LOSS/THRESHOLD FREQUENCY

Performance objectives are most appropriately developed through a cooperative effort of the user, the design team, and the engineering team. For this exercise using the Ship Firesafety Engineering Method (SFSEM), the objectives were developed through a detailed evaluation of the compartments of the PIR design by the icebreaker design team and the SFSEM team. The evaluation was conducted on 20 March 1987 with G-ENE-4, G-ENE-5A, G-ENE-5C, G-ENE-5D, G-ENE-5E and G-OIO representatives providing the technical input. It is significant to note that fire safety objectives for Coast Guard vessels are not routinely specified during design. This lack of prior focus made the development of objectives difficult and the final result did not include direct input by Coast Guard operations management.

The design team was asked to categorize fire safety objectives for all compartments on the icebreaker, including the magnitude and frequency of fire loss which would be unacceptable. The mission critical loss was defined by assigning an Unacceptable Loss (see Table 4.1) and a threshold frequency of the unacceptable loss.

TABLE 4.1
UNACCEPTABLE LOSS DEFINITIONS

uloss.out
10/30/1987

Loss#	Type of Loss
1	Fire reaches established burning.
2	Major item involved in fire
3	Full compartment lost to fire
4	2 compartments of one type lost to fire
5	3 compartments of one type lost to fire
6	4 compartments of one type lost to fire
7	5 compartments of one type lost to fire
8	All compartments of one type lost to fire

For practical purposes the threshold frequency of unacceptable loss was limited to the following choices even though it is a continuous function:

A. 1 per year
B 0.33 per year
C. 0.1 per year
D. 0.033 per year
E. 0.01 per year
F. 0.0033 per year
G. 0.001 per year

The mission critical unacceptable loss defines the magnitude of the fire loss needed to cause loss of ship mission capabilities. This may range from very small volumes for critical electronic gear to many compartments where the rooms are not critical to mission performance. The threshold frequency of unacceptable loss defines the likelihood of a mission critical loss which would be unacceptable to the Coast Guard and the nation. Level D, for example, corresponds to a loss once in 30 years, the normal lifetime of a vessel.

The fire safety objectives determined for each compartment of the ship are shown in Appendix D, Fire Safety Objectives, as unacceptable loss (uloss) and threshold frequency of unacceptable loss (Freq uloss). Also included in the table is the frequency of established burning estimated from historical Navy data for similar compartments. It is significant to note that the threshold loss frequency is in every case greater than the frequency of established burning. This indicates that in the absence of multi-room fires, the objectives will be met even if all fires grow to fully consume the compartment.

After the exercise to assign fire safety objectives was completed it became obvious that they were not very stringent or realistic. Further work may be required to more clearly define the fire safety objectives and relate them to the actual fire safety experience on operating Coast Guard cutters. Economically based models should also be considered for augmenting the process. It should be pointed out that the current method of considering single compartment types does not include the effects of simultaneous loss of several different compartment types. These effects are under study and will be reported separately.

IMPLEMENTATION OF THE OBJECTIVES

While the objectives were set according to levels of loss indicated above, it was not possible to use all the information. In particular, the SFSEM does not at present allow identification of losses of single objects within a compartment; hence, Level 2 cannot be resolved. All Level 2 losses were taken as Level 1 to be conservative.

The SFSEM does not calculate specific fire scenarios; hence, it is not possible to determine the likelihood of two rooms being lost together unless the events are assumed independent. Under this assumption the likelihood of losing two compartments is simply the product of their respective loss probabilities.

5.0 FIRE HAZARDS ON PIR

Fire hazards include the likelihood of having a fire, the amount of combustibles in a compartment, the probability that a fire will grow to full room involvement and the heat energy it will release prior to and after full room involvement up to burnout. The probability that a fire will grow is affected by fuel distribution in and ventilation to a compartment. All cf these factors are discussed in this section and quantified for the PIR. These quantities are then used in conjunction with the results of Sections 6.0 and 7.0 as input for the flame movement analysis discussed in Section 8.0.

5.1 FIRE FREQUENCY (FREQUENCY OF ESTABLISHED BURNING)

The objective of this analysis was to determine the expected frequency of fires, expressed as the ratio of number of fires to the period of exposure. Separate ratios were determined for several different types of shipboard compartments. The frequency ratios to be presented were calculated from historical data for selected types of U.S. Navy vessels. The historical data covered the period 1975 through 1986. Casualty data for fires aboard U.S. Coast Guard vessels was not included in this analysis, primarily because of the difficulty in making an accurate estimate of the operational time (exposure) for Coast Guard vessels that have now been decommissioned for many years. Overall exposure time for similar types of Navy vessels was much greater. Therefore, the effect of excluding the Coast Guard vessel data has little effect on the resultant frequencies.

The number of fires that occurred during 1975-86 in each type of compartment was obtained from fire casualty data compiled by the U.S. Naval Safety Center (1). This data is based on formal casualty reports received from the individual ships. It is possible that relatively small fires that were extinguished with only minor damage were not formally reported. Therefore it is likely that frequencies calculated directly from this data will more nearly approximate the frequency of serious fires than the frequency of ignition.

The unit "compartment-year" was selected as the measure of exposure to be used in calculating the fire frequency ratios. In order to determine the total exposure for each compartment category, it is necessary to determine the types and numbers of the compartments aboard each class of ship included in the analysis, as well as the operational history of each individual ship in the sample. For a given type of compartment (e.g., engine room), the total overall exposure will be the sum of the exposures that occurred aboard all of the individual vessels in the sample. For example, the engine room exposure increment provided by an individual ship would be the product (number of engine room compartments aboard the ship) x (number of years during which the ship was in operation during the 1975-86 period).

The numbers of each type of compartment aboard each class of vessel included in the analysis were obtained from Ship Compartment Directory data obtained from the U.S. Naval Sea Systems Command (2). Compartment lists were obtained for fourteen of the twenty-one vessel classes involved. Similar data for the remaining classes was not available; these were older ships that were taken out of service during the 1975-86 period, and compiled a relatively small portion of the operating time provided by the entire sample. In cases where no compartment list was available, ships were assumed to have the same types and numbers of compartments as a similar ship for which a compartment list had been obtained.

For this analysis, the sample included all U.S. Navy cruisers, destroyers and frigates that were in active status at any time during the period 1 January 1975 through 31 December 1986. Many of these vessels were commissioned prior to 1975, and remained active throughout the entire 12-year period. For a ship that joined the fleet during 1975-86, the time in active service was assumed to begin on its commissioning day. Time in active status was assumed to stop on the date that a vessel was decommissioned (or, in some cases, on the date that the ship was stricken from the U.S. Naval Vessel Register) or transferred to Naval Reserve Training status. Time undergoing overhaul was not considered as active status. Dates for individual vessels were taken from references 3, 4 and 5. The ship classes that were included in the sample are listed in Table 5.1.

For the purposes of this analysis, a three-character compartment code was set up so that the spaces with similar functions or contents could be grouped together when preparing the compartment totals for the individual vessel classes. The three-character code is based on the existing Navy/Coast Guard Compartment Use letter system (6), and in each case includes the same initial letter. The three-character code allows a more detailed breakdown than the existing system, so that individual types of compartments can be examined separately. Examples are Offices: code QOX; Shops: code QPX; and Fan Rooms: code QFX.

Table 5.2 presents the fire frequencies (fires per compartment-year) for various types of compartments. The Calculated Fire Frequency values were developed directly from the available data, as described above. Adjusted Fire Frequency values were obtained by doubling the Calculated Fire Frequency values on the assumption that half of the actual established-burning fires are not reported. In the case of compartment types where no fires were reported, an arbitrary Adjusted Fire Frequency value of .0001 was selected.

The Adjusted Fire Frequency was then used as the basis for assigning a fire frequency for every compartment on the PIR. These are summarized in Figure 5.1 and listed in Appendix D, Fire Safety Objectives, in the column labeled Freq. EB. These values are used in the flame movement analysis simulations discussed in Section 8.1.

TABLE 5.1
SHIPS CONSIDERED IN FIRE FREQUENCY ANALYSIS

Vessel Class	Number of Individual Vessels in Active Status	Period in Active Status
Guided Missile Cruisers		
CG 47	5	1983-86
CG 26	9	1975-86
CG 16	9	1975-86
CG 10	3	1975-80
CG 4	2	1975-79
Heavy Cruiser		
CG 148	1	1975
Guided Missile Destroyers		
DDG 993	4	1981-86
DDG 37	10	1975-86
DDG 35	2	1975-78
DDG 31	4	1975-83
DDG 2	23	1975-86
Destroyers		
DD 963	31	1975-86
DD 945	5	1975-83
DD 931	9	1975-83
DD 710	18	1975-79
Guided Missile Frigates		
FFG 7	49	1977-86
FFG 1	6	1975-86
Frigates		
FF 1052	46	1975-86
FF 1040	10	1975-86
FF 1037	2	1975-86
FF 1098	1	1975-86

NOTE: The dates shown in the "Period in Active Status" column for each vessel class indicate the period in which at least one vessel of the class was in active status during the 1975-86 analysis period.

TABLE 5.2
FIRE FREQUENCY DATA

Type of Compartment	Number of Fires Reported	Fire Frequency (Fires/Compt Year) Calculated	Adjusted
Storage Spaces			
Flammable liquids storage	4	0.00073	0.0015
Other storerooms and lockers	50	0.00044	0.0009
Electrical/Electronic Equipment Spaces			
(including ship control, fire control, communication and electrical and electronic equipment spaces)	29	0.00061	0.0012
Propulsion Machinery Spaces			
Engine rooms	73	0.02368	0.0474
Boiler rooms	64	0.02258	0.0452
Auxiliary Machinery Spaces			
Generator/motor generator rooms	6	0.00156	0.0031
Emergency/auxiliary generator rooms	23	0.01021	0.0204
Pump rooms	3	0.00100	0.0020
Steering gear rooms	7	0.00365	0.0073
Anchor windlass machinery rooms	11	0.00550	0.0110
Other auxiliary machinery spaces	41	0.00167	0.0033
Fan rooms	7	0.00019	0.0004
Offices, Laboratories and Shops			
Office spaces	5	0.00020	0.0004
Laboratory spaces	0	--	0.0023
Shop spaces	15	0.00113	0.0023
Accommodation Spaces			
Berthing spaces	18	0.00042	0.0008
Mess spaces	4	0.00059	0.0012
Recreation spaces	3	0.00032	0.0006
Medical/dental spaces	0	--	0.0001
Sanitary spaces	4	0.00008	0.0002
Food preparation spaces	9	0.00107	0.0021
Laundry spaces	5	0.00182	0.0036
Passageways	3	0.00005	0.0001
Magazines and Weapons Spaces			
Ammunition/weapons handling spaces	0	--	0.0001
Armories/small arms storage spaces	0	--	0.0001
Weapons magazines	1	0.00006	0.0001
Small arms magazines	0	--	0.0001

TABLE 5.2
FIRE FREQUENCY DATA (cont'd)

<u>Helicopter areas</u>			
Helicopter hangars	3	0.00190	0.0038
Helicopter landing areas	5	0.00353	0.0071
<u>Miscellaneous Spaces</u>			
Wiring trunks	0	--	0.0001
Intake trunks/plenums	0	--	0.0001
Exhaust trunks/uptakes	4	0.00062	0.0012
Vertical access trunks	0	--	0.0001
Void spaces	1	0.00013	0.0003

5.2 COMPARTMENT FUEL LOAD

The fuel loading (also called the fire load) summarizes the heat energy available for release from combustible materials in a compartment. It is actually a fuel load density in that the total quantity of heat capable of being released in complete combustion is divided by a reference area. In the United States, that reference area is the floor area within the compartment. The fuel load density, called the fuel load in this report, can be calculated for any compartment as

$$q_f = \frac{mH}{A_f} \qquad (1)$$

where,

q_f = fuel load, Btu/sq.ft.

A_f = floor area, sq.ft.

m = weight of combustible fuels, lb

H = heat energy content in the material for complete combustion, Btu/lb

It would be possible to identify the fuel load rather accurately by weighing each piece of combustible material and multiplying that weight by the heat energy content in Btu/lb. Applying Equation (1) *for a compartment* would provide the fuel loading. This process would be correct only for the combustible materials in the compartment at the time of measurement. A variation in the fuel load will occur as combustible materials move into and out of the compartment through routine use and operation of the ship. In the PIR this variation is expected to be small for most routine work or accommodation compartments. Storage compartments and scientific research compartments are expected to have a significant fuel load variation, depending upon the nature and containment characteristics of the materials.

FIGURE 5.1: ESTIMATED FREQUENCY of EB for PIR COMPARTMENTS (5 pages)

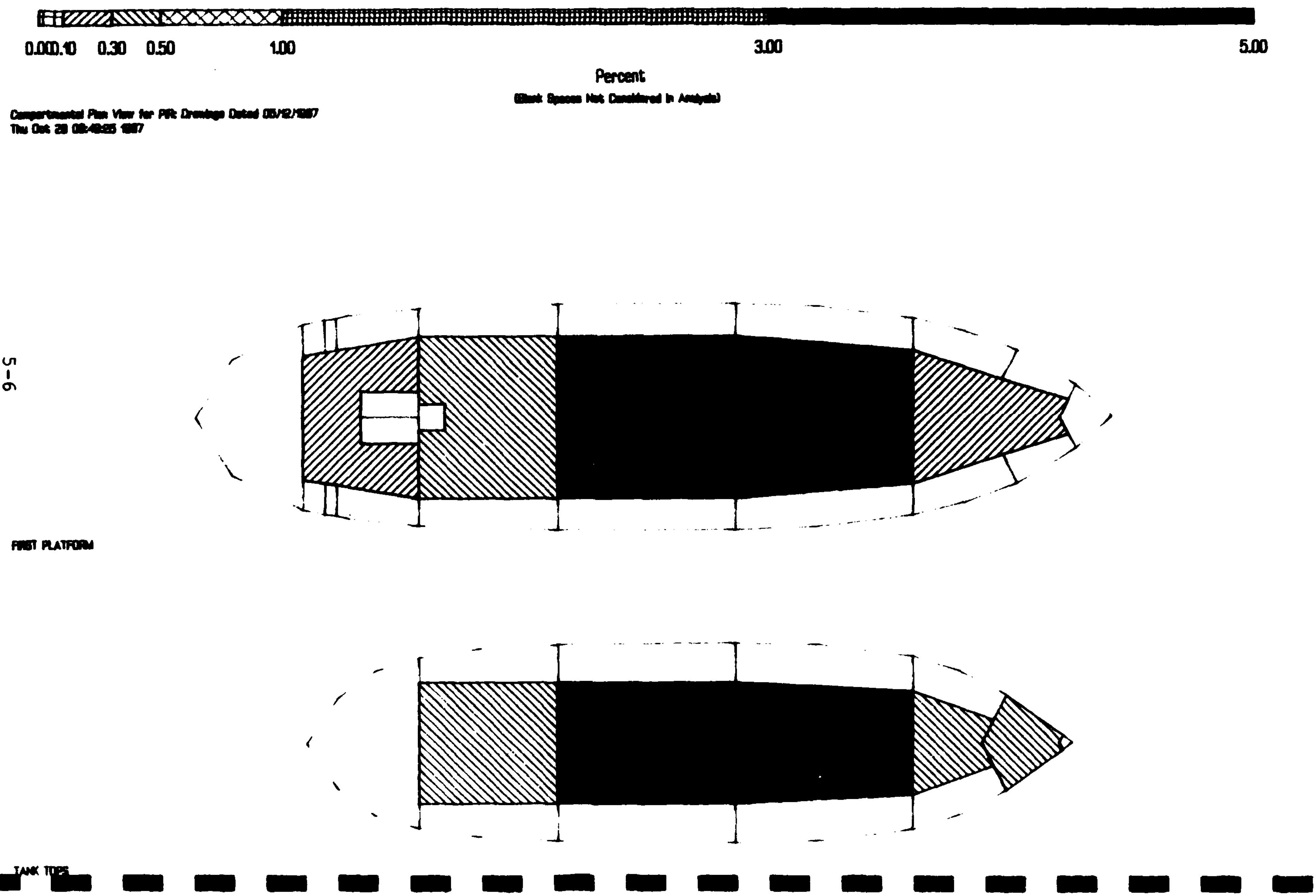


FIGURE 5.1: ESTIMATED FREQUENCY of EB for PIR COMPARTMENTS (5 pages)

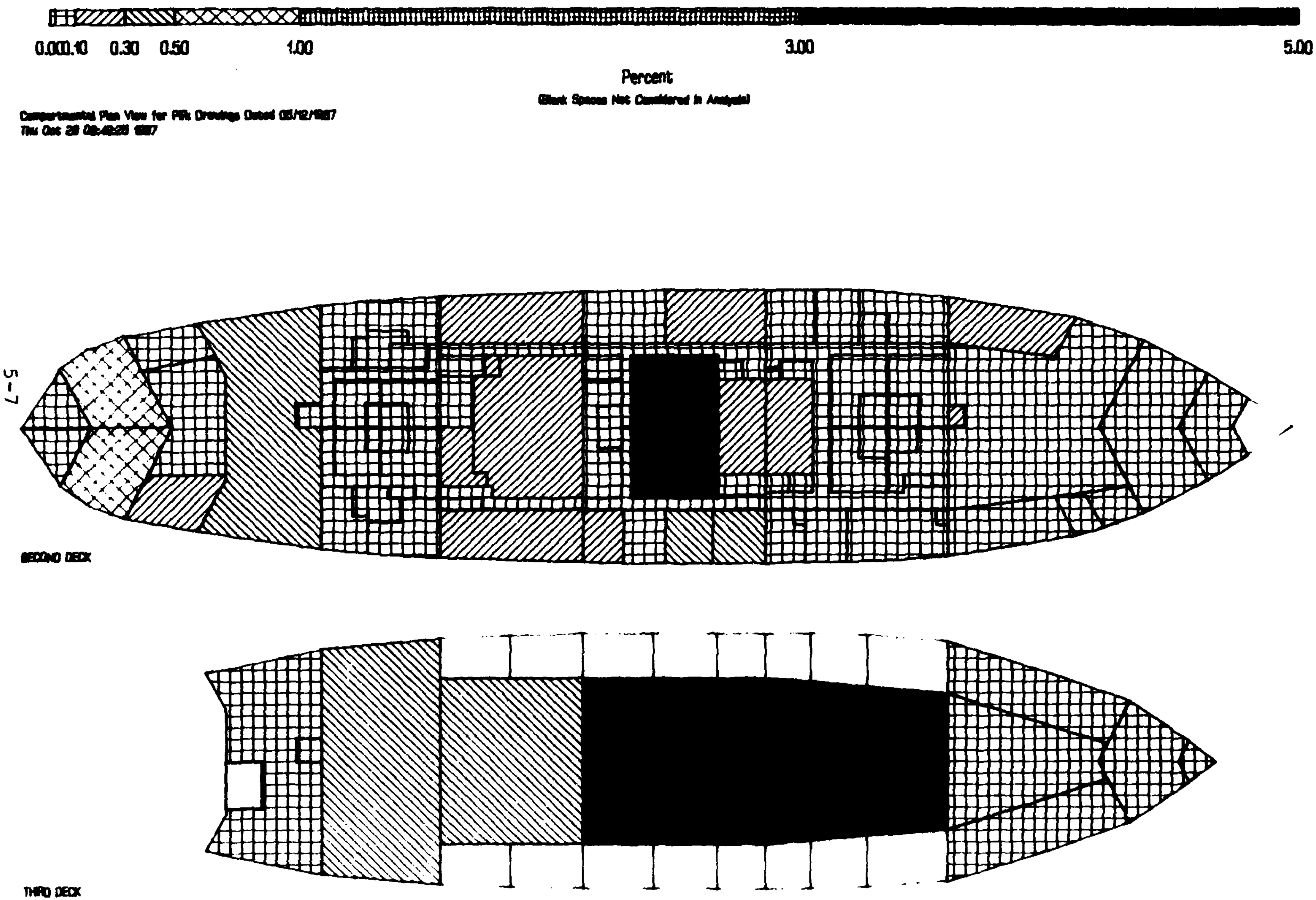


FIGURE 5.1: ESTIMATED FREQUENCY of EB for PIR COMPARTMENTS (5 pages)

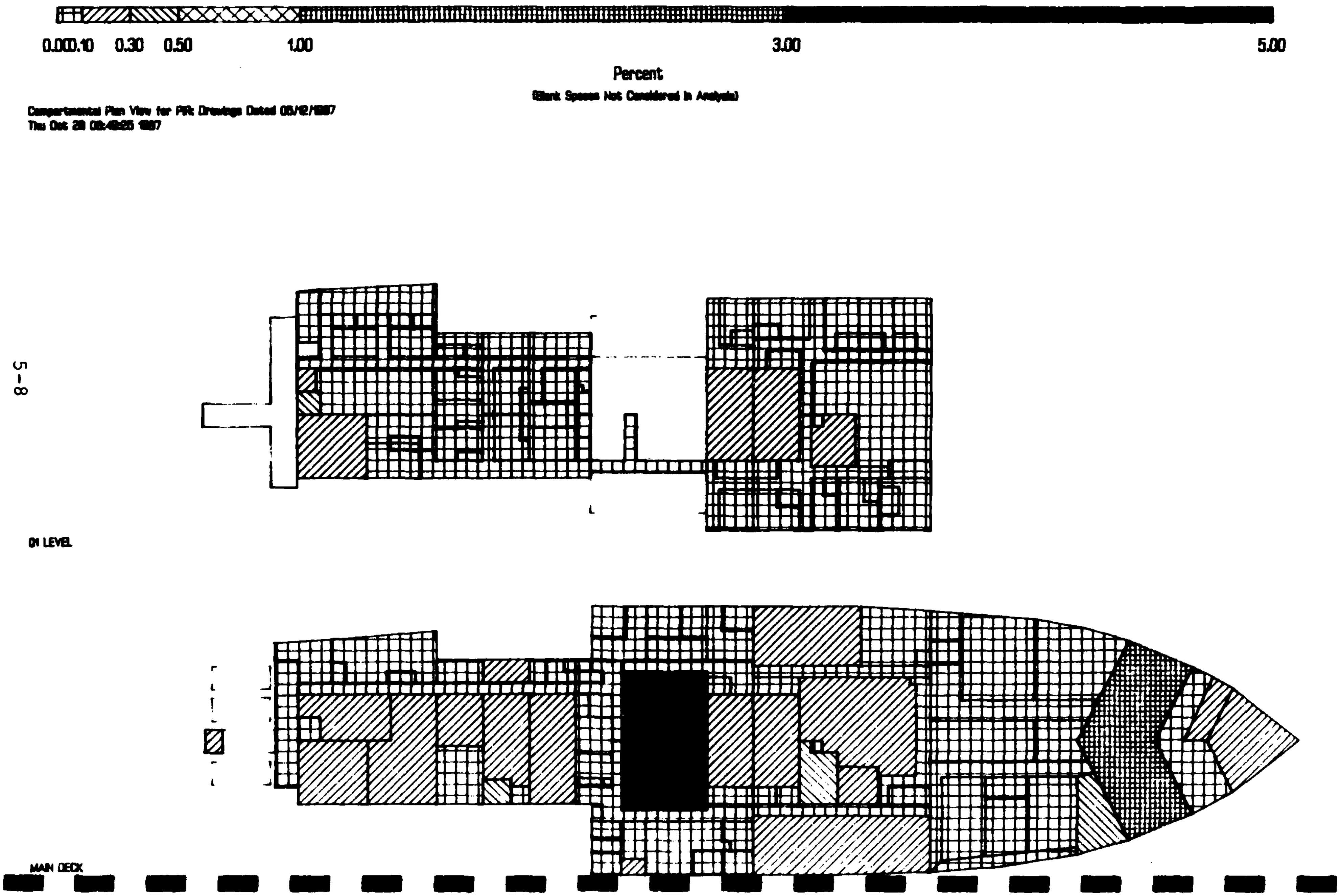


FIGURE 5.1: ESTIMATED FREQUENCY of EB for PIR COMPARTMENTS (5 pages)

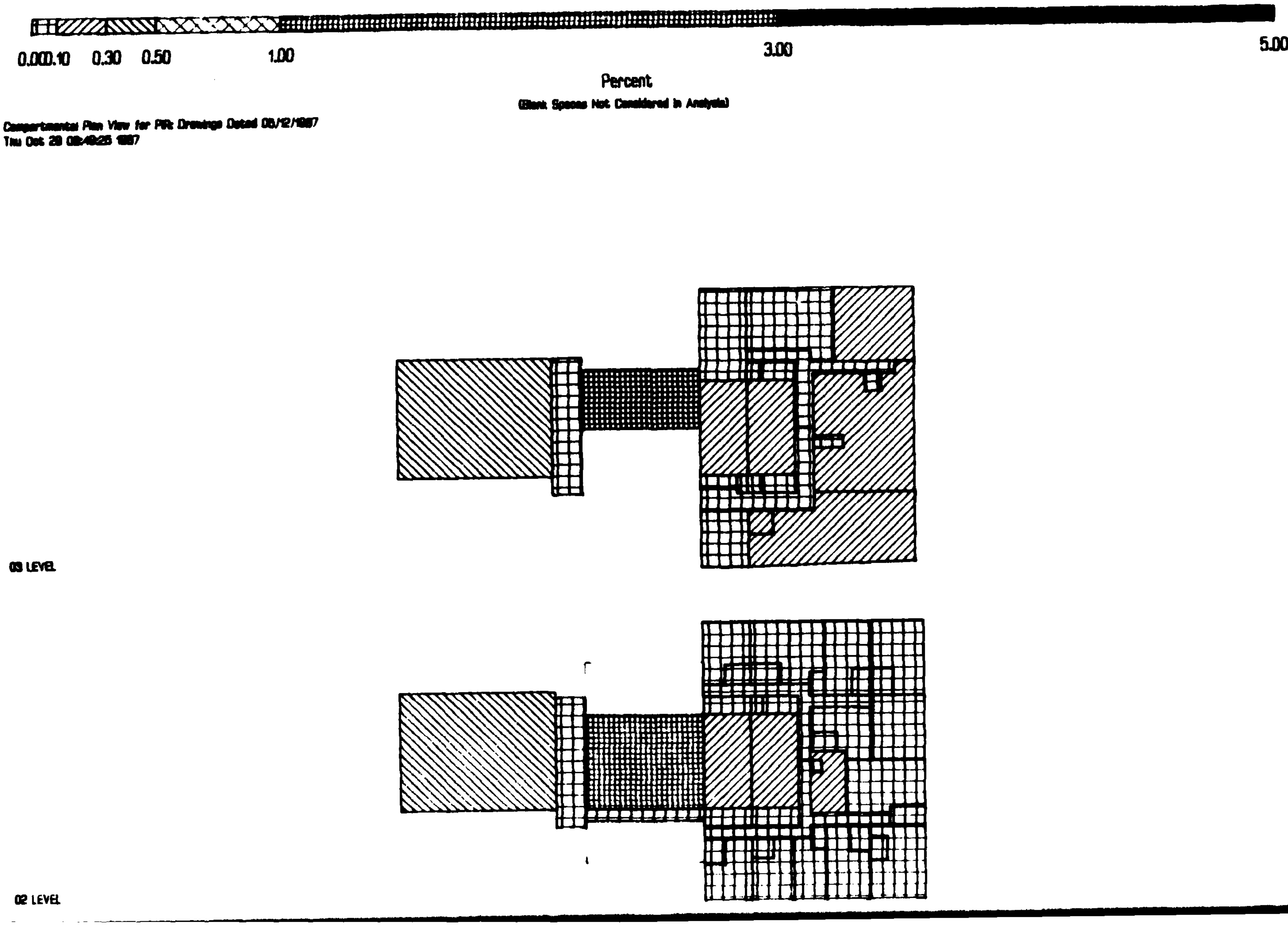
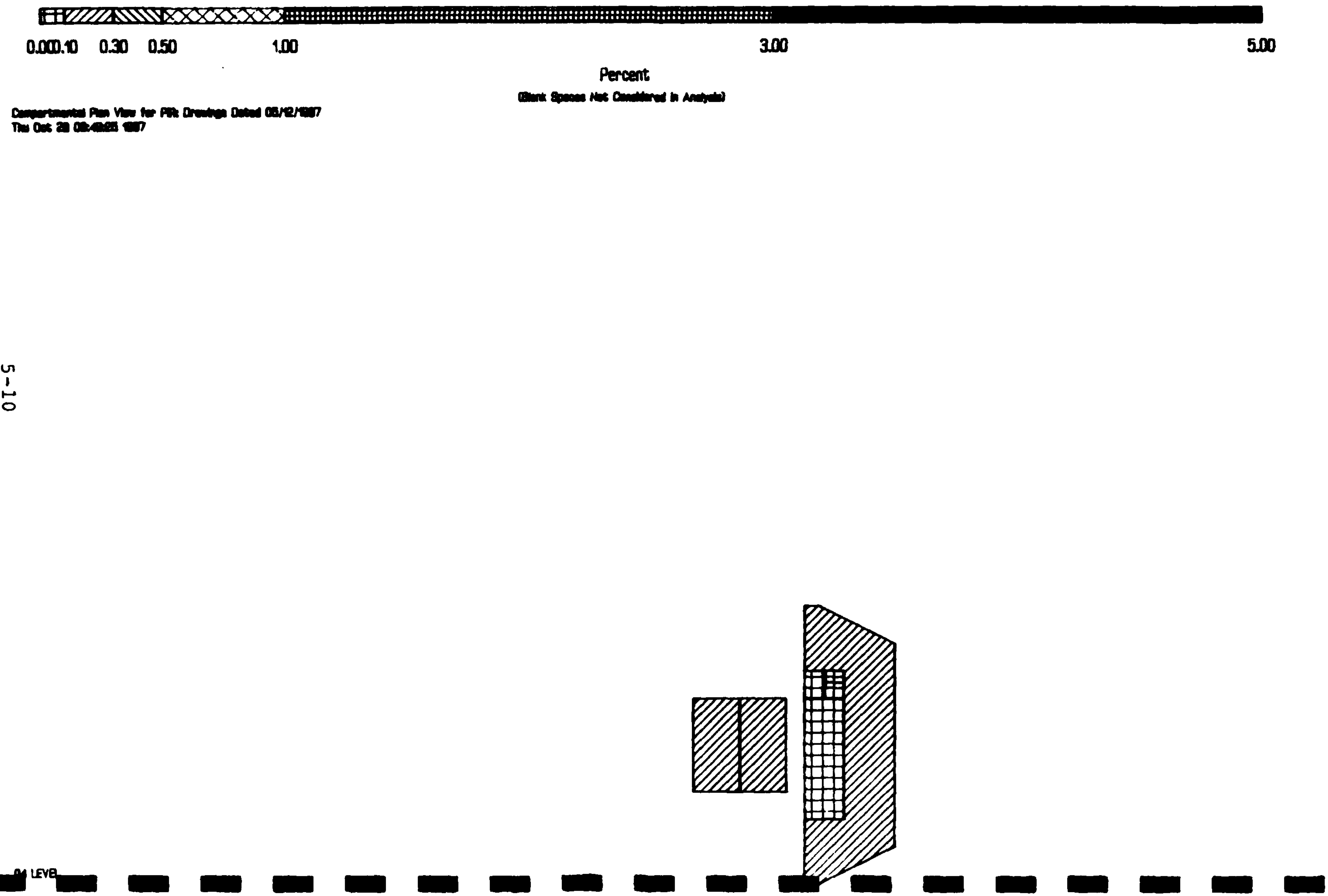


FIGURE 5.1: ESTIMATED FREQUENCY of EB for PIR COMPARTMENTS (5 pages)



The heat energy content of wood is approximately 8000 Btu/lb. Plastics and other petroleum-based fuels have a heat energy content ranging from 9000 - 20,000 Btu/lb. For convenience and by normal convention, it was assumed that all cellulosics have H = 8000 Btu/lb and all petroleum based fuels have H = 16,000 Btu/lb. These values are used in conjunction with Equation (1).

The fuel loads for the PIR were obtained by using the concepts described above and by estimating the weights of combustible contents for each compartment. The estimates were guided by three types of experience: (1) previous experience in estimating fuel loads for building fire safety analyses; (2) accurate fuel load measurements from experimental compartment burnout tests, as illustrated in References 7 and 8; and (3) observing and photographing fuel loads in compartments on the POLAR SEA and 210-foot cutters. The fuel loads were obtained by estimating the fuel load for the various compartments on the POLAR SEA and 210-foot cutters and then assigning this value to the compartment most similar to it on the PIR. The fuel load estimates were subdivided into an estimate for cellulosic materials (Class A) in a compartment and one for petroleum-based liquids (Class B) in the compartment. The estimates for each of these are summarized in Figure 5.2 and listed in Appendix E, Fire Hazards, for each compartment along with the compartment's floor area.

5.3 PROBABILITY OF SELF LIMITING FLAME (I VALUE)

Ignition and established burning within a compartment identifies the start of the shipboard fire safety design. Given established burning, a fire will either self-terminate before the room becomes fully involved or the fire will continue to develop to full room involvement. The relative ease and speed with which a fire can develop or terminate depends upon:

a) the fuel: the amount, type, arrangement, and interior finish

b) the air supply

c) the room construction: ceiling height, compartment volume, compartment shape, and boundary thermal characteristics.

These factors influence strongly the subsequent fire development in the compartment. The fire growth hazard potential for different compartments will vary, depending upon the relative influence of the factors noted above. The I-Value is used to describe the fire growth hazard potential for a room. Different I-Values are used to compare room hazards.

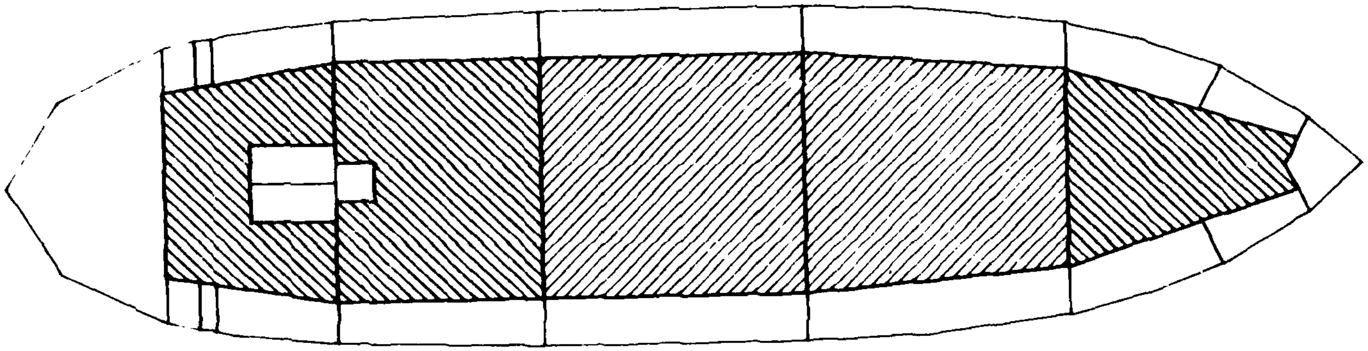
The I-Curve is defined as the probability that a fire will self terminate. It is a cumulative probability distribution in that

FIGURE 5.2: ESTIMATED FUEL LOAD for PIR COMPARTMENTS (5 pages)

500.00 - 3000.00	1000 BTU's / sq ft	
100.00 - 500.00		
50.00 - 100.00		
10.00 - 50.00		
1.00 - 10.00		
0.00 - 1.00		

(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Wed Oct 28 14:28:41 1987



FIRST PLATFORM

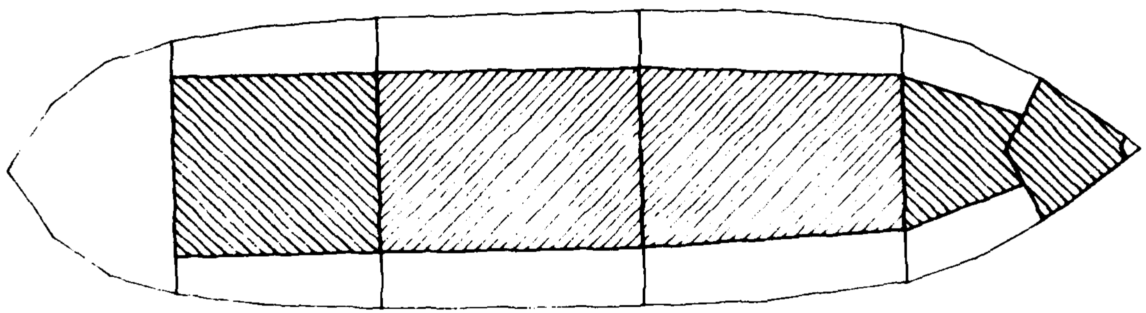


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FIGURE 5.2: ESTIMATED FUEL LOAD for PIR COMPARTMENTS (5 pages)

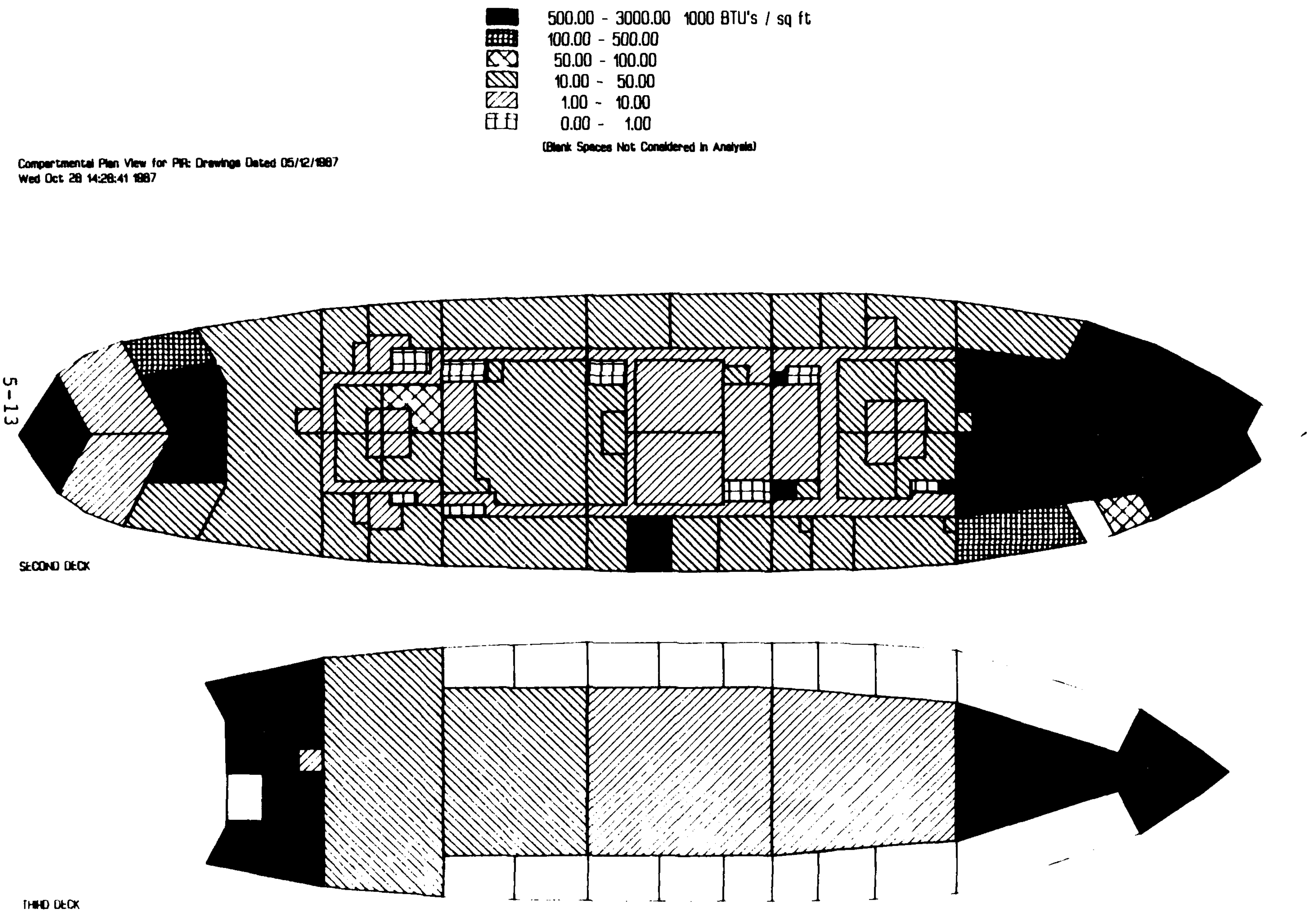


FIGURE 5.2: ESTIMATED FUEL LOAD for PIR COMPARTMENTS (5 pages)

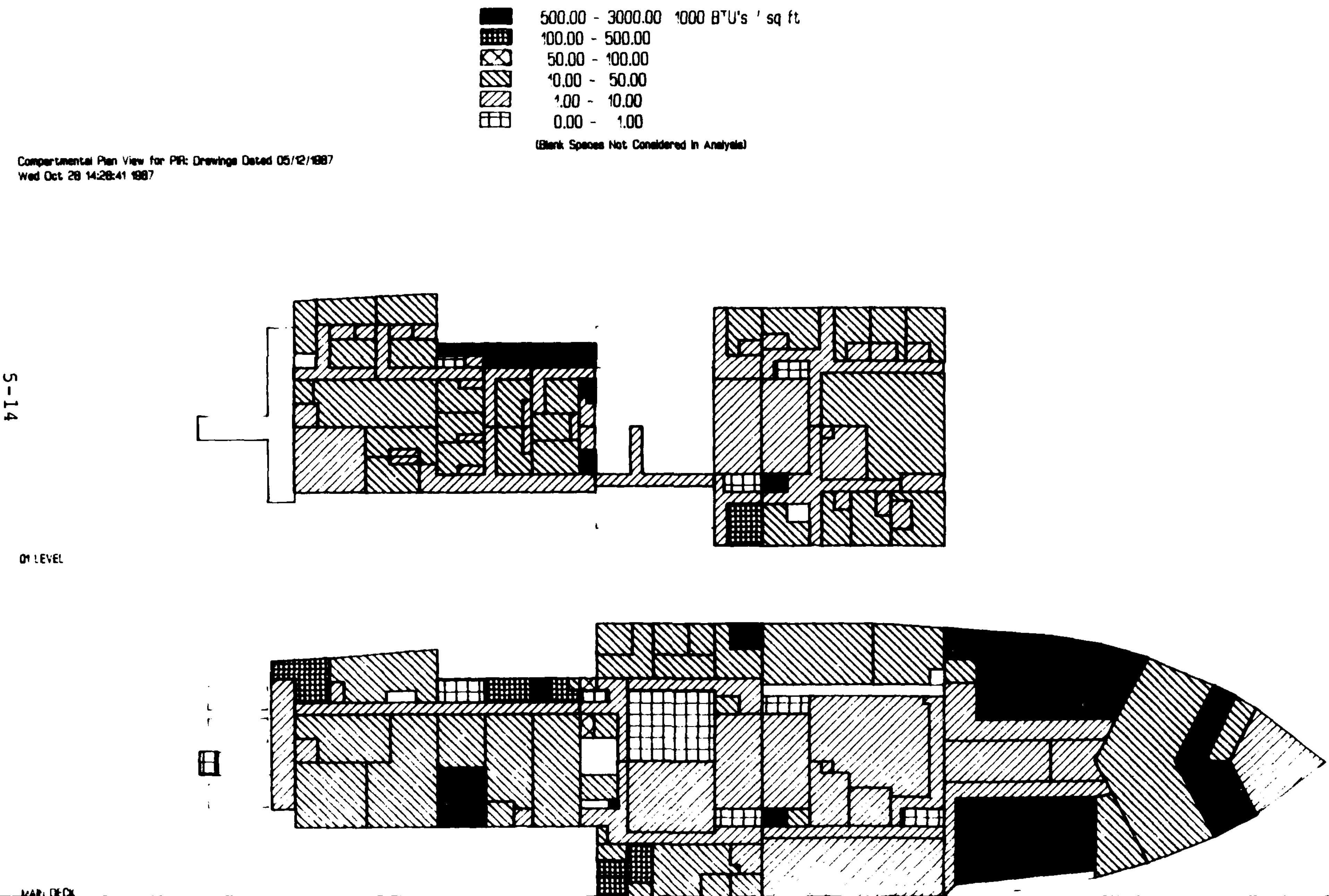
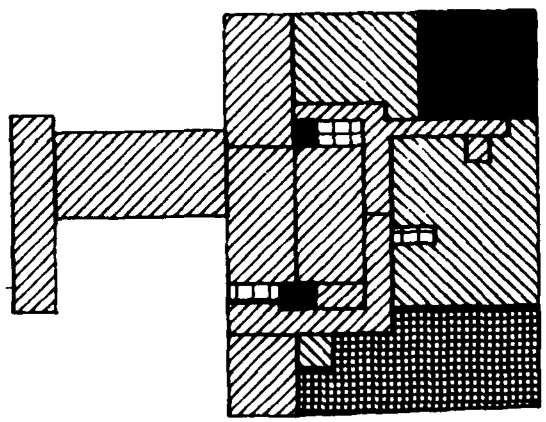


FIGURE 5.2: ESTIMATED FUEL LOAD for PIR COMPARTMENTS (5 pages)

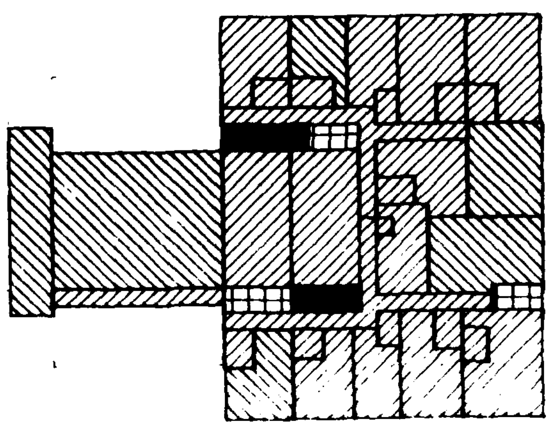
500.00 - 3000.00	1000 BTU's / sq ft
100.00 - 500.00	
50.00 - 100.00	
10.00 - 50.00	
1.00 - 10.00	
0.00 - 1.00	

(Blank Spaces Not Considered in Analysis)

Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Wed Oct 28 14:28:41 1987



03 LEVEL

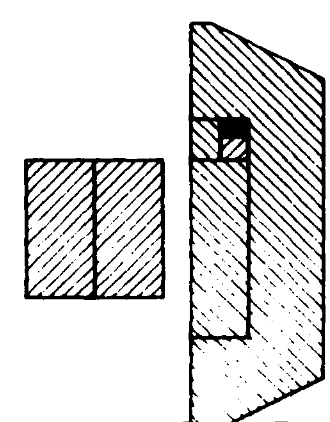


02 LEVEL

FIGURE 5.2: ESTIMATED FUEL LOAD for PIR COMPARTMENTS (5 pages)

500.00 - 3000.00 1000 BTU's / sq ft
100.00 - 500.00
50.00 - 100.00
10.00 - 50.00
1.00 - 10.00
0.00 - 1.00
(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 06/12/1987
Wed Oct 28 14:28:41 1987



04 LEVEL

fire grows through realms. The I-Curve answers the question: given the fire has reached this realm, what is the probability that it will grow to the next realm size? This process enables a single scenario to be constructed. However, the ignition location is not necessarily known. Consequently, a number of potential fire scenarios could exist for any room. An I-Curve must be selected to reflect the relative fire growth hazard for the space. At the present time, the I-Curve is a subjective judgment of the evaluation that best represents the relative fire growth characteristics of the room. A low I value (e.g., 5% or 10%) represents a high likelihood that given established burning, a fire will involve the entire room. Conversely, an I value of 90% or 95% indicates that the room is relatively fuel sterile, and it would be difficult for a fire to reach full room involvement.

The I-Curve values for the compartments on the PIR were based on the following: (1) experience in developing I-Curve values for buildings in other analyses; (2) observations of compartment burnout tests conducted by the U.S. Coast Guard R&D Center (7,8); and (3) similar compartments on the POLAR SEA and 270-foot Coast Guard Cutters. The resultant I values are summarized in Figure 5.3 and presented in Appendix E, Fire Hazards.

5.4 PRE-FLASHOVER AND FULL ROOM INVOLVEMENT (FRI) TIME

The time required for fire development from EB to FRI was estimated using the McCaffrey algorithm (9) described in Appendix G, Calculation of Full Room Involvement Time, for compartments of fire origin and subsequent compartments which became involved through thermal failure of barriers (T failures). The algorithm requires a knowledge of the heat release rate history, the compartment ventilation openings, and the barrier thermal properties.

The initial heat release rate, Q, was modeled as proportional to the time from EB squared, $Q = (\text{alpha})t^2$, to a maximum heat release rate, Qmax. Qmax is maintained for a duration, tcrit. The constants alpha, Qmax, and tcrit, were determined by a comparison of compartment contents with items for which heat release rate data was available from the literature. A summary of literature heat release rate data will be provided in a separate report. Appendix G, Calculation of Full Room Involvement Time, demonstrates the methods used in developing heat release rates. Appendix H, Pre-Flashover Data and FRI Time, presents the values assigned to the constants for each compartment on the PIR.

Ventilation rates were taken to be dominated by forced ventilation during the pre-FRI period. Ventilation rates used are summarized in Appendix F, Compartment Ventilation, in terms of the time to completely exchange the air in a compartment (Exch.) and the flow rate to accomplish it (Flow). The thermal properties of the barriers included on the PIR are discussed and presented in Section 6.0.

FIGURE 5.3: PROBABILITY of FLAME LIMITING ITSELF for PIR COMPARTMENT (5 pages)

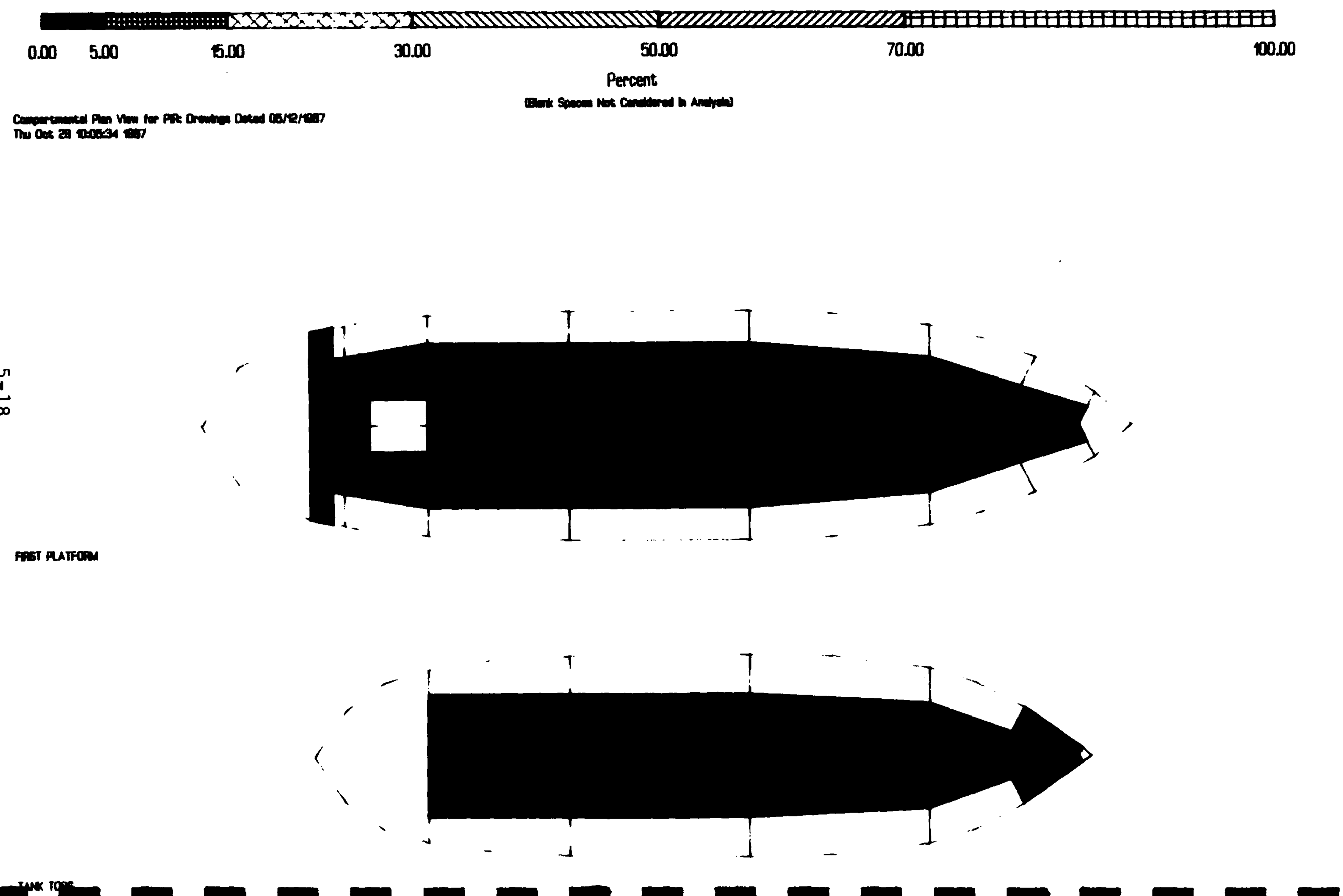


FIGURE 5.3: PROBABILITY of FLAME LIMITING ITSELF for PIR COMPARTMENT (5 pages)

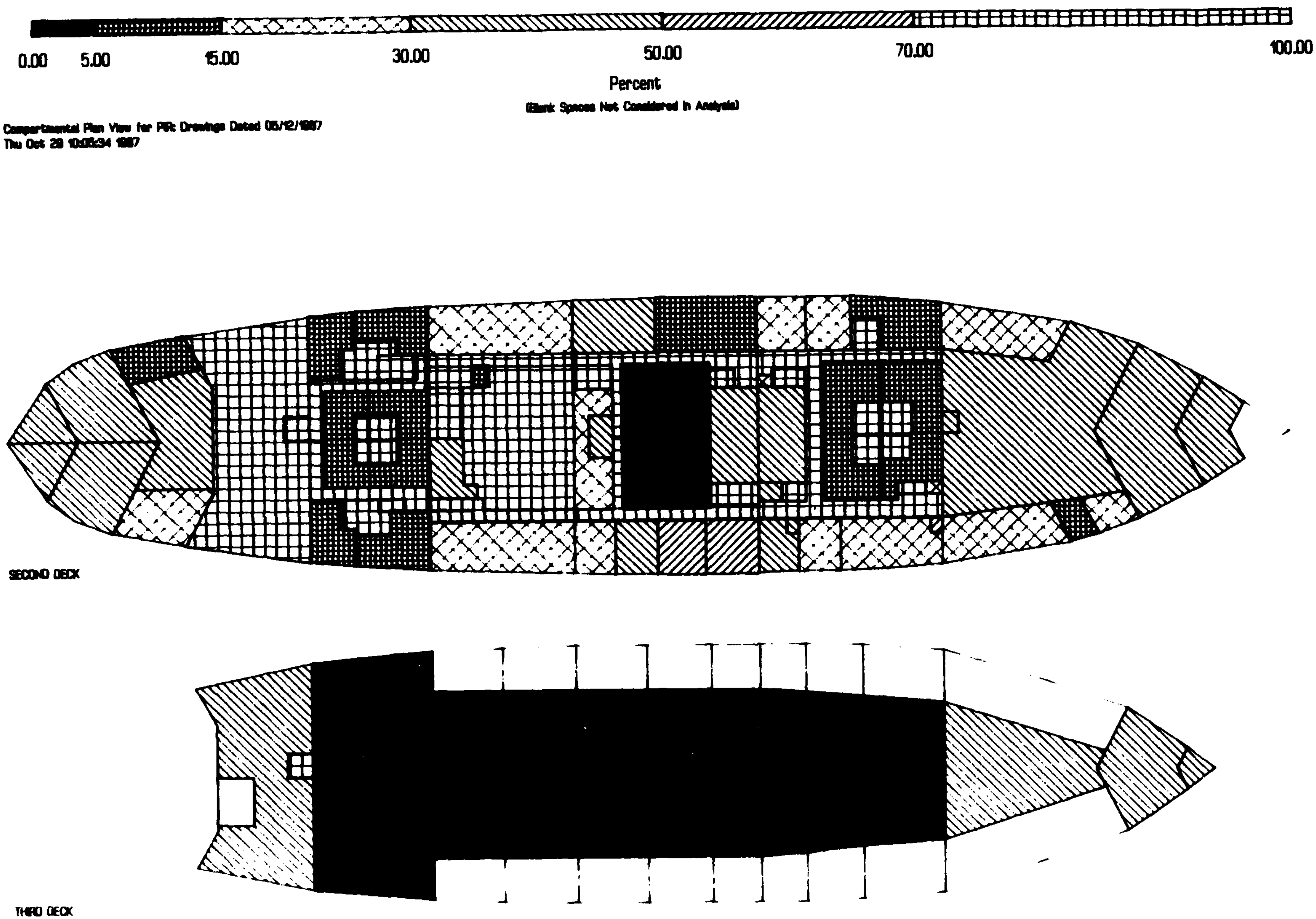


FIGURE 5.3: PROBABILITY of FLAME LIMITING ITSELF for PIR COMPARTMENT (5 pages)

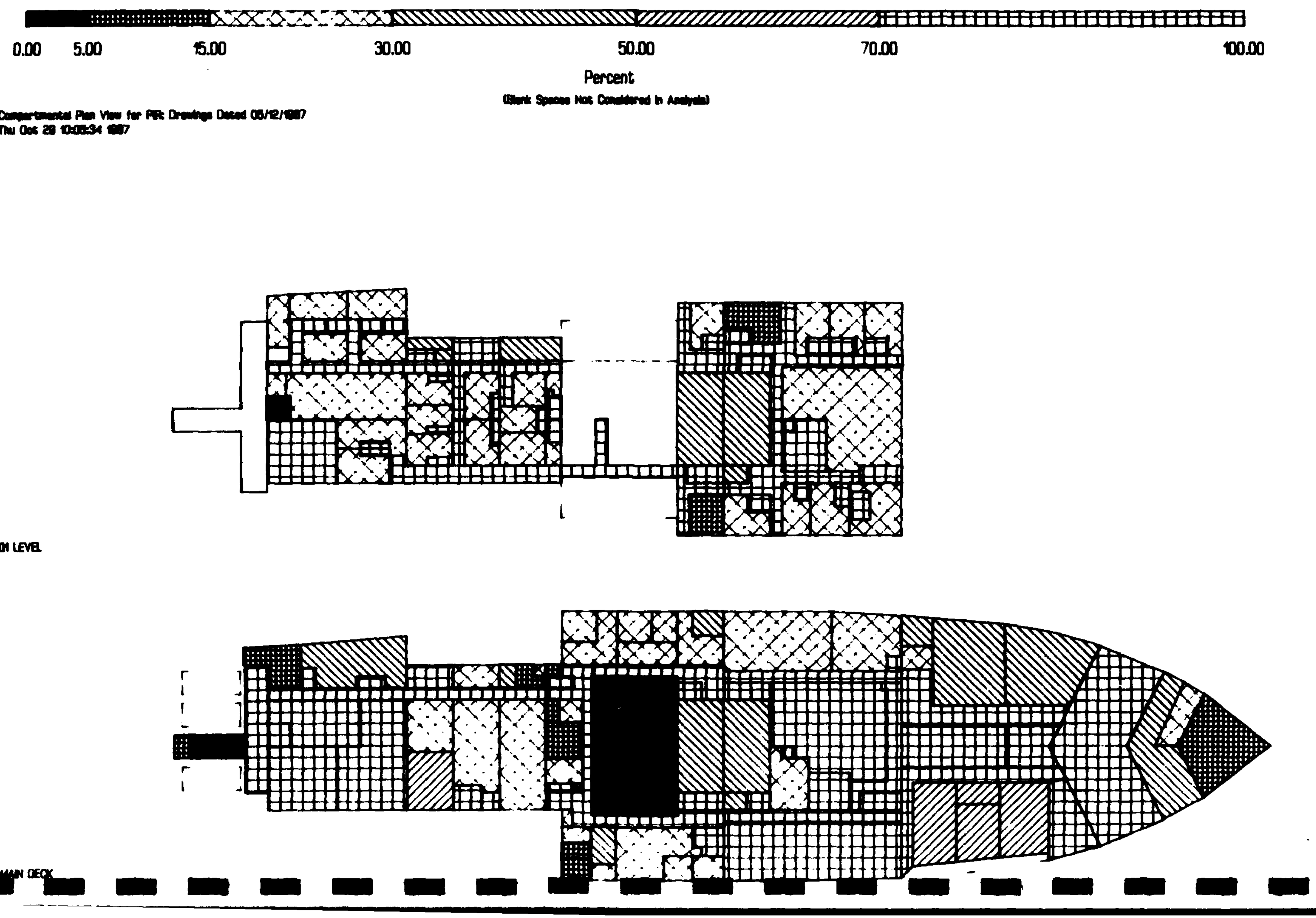


FIGURE 5.3: PROBABILITY of FLAME LIMITING ITSELF for PIR COMPARTMENT (5 pages)

Percent

(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 05/12/1987
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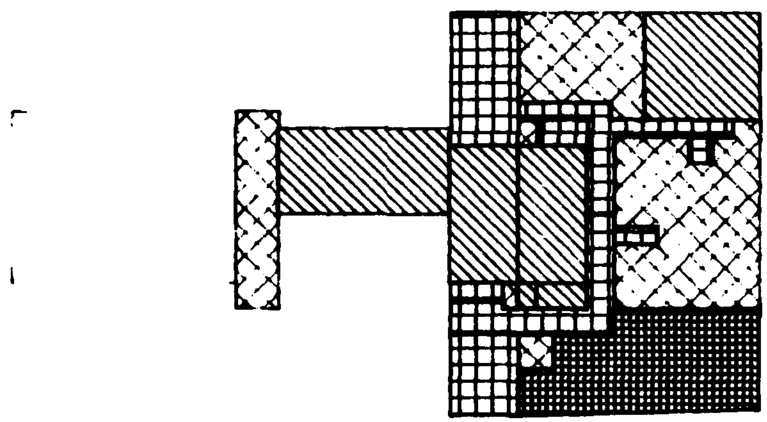
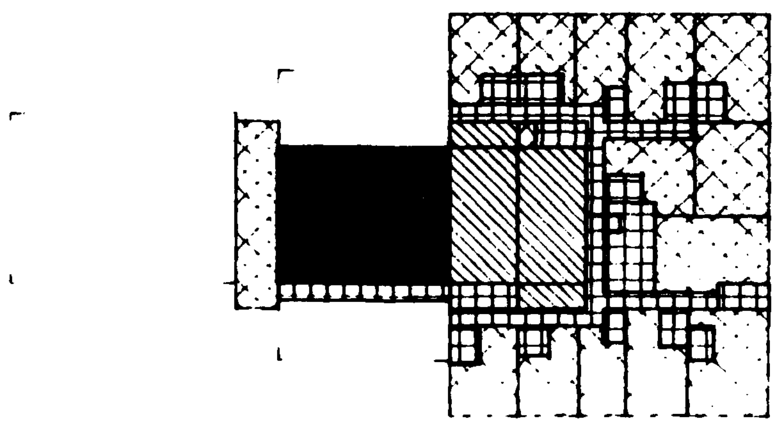
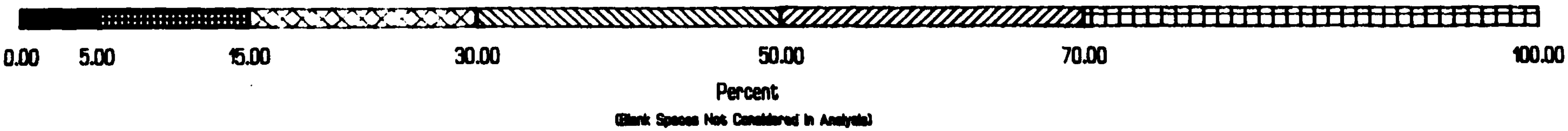


03 LEVEL



02 LEVEL

FIGURE 5.3: PROBABILITY of FLAME LIMITING ITSELF for PIR COMPARTMENT (5 pages)



Compartmental Plan View for PIR: Drawings Dated 05/12/1987
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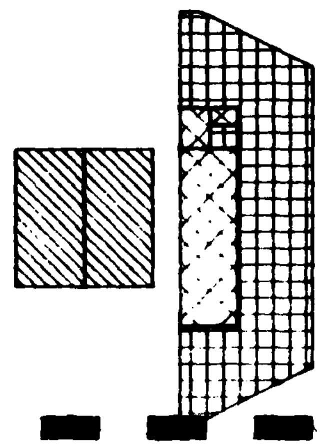

04 LEVEL

The results of this analysis were unsatisfactory, with FRI times taking on extreme values around one minute or in excess of 1000 minutes. The unrealistic results appear to arise from the low ship ventilation rates relative to the natural convection dominated fires considered by McCaffrey's method and experiments. This is being studied further.

In the absence of a reliable analytical technique, the FRI times for compartments of fire origin, t^0_{FRI}, were estimated by the team using heuristic methods. The resulting assigned values for FRI time are shown in Appendix H, Pre-Flashover Data and FRI Time. Rooms subsequent to the room of origin were assigned the same FRI time for thermal barrier failure. For massive barrier failures (Dbar failures) t_{FRI} was determined by adjusting t^0_{FRI} for the fraction of heat released in the previous compartment which is transported through the failed barrier into the space in question. This determination is made in the simulation program, since it depends upon which barrier fails. This information cannot be determined prior to the simulation.

5.5 POST-FLASHOVER RATE OF HEAT RELEASE

The duration and heat release rate during the post-FRI period is well known to be controlled by the fuel load and the compartment ventilation (10). The rate of heat release is simply dictated by the availability of air. The heat release rate is given by the air inflow rate, m, multiplied by the heat released per unit mass of air consumed. The air inflow rate during this period can be shown to be $m = 0.5\, A\sqrt{H}$, where A is the vent area in m^2 and H is the height of the vent in meters, and m is in kg/s. This result can be extended to multivent situations using the following approximations.

$$A = \mathrm{sum}_i(A_i) \quad \text{and} \quad H = (1/A)\ \mathrm{sum}_i(A_i H_i)$$

where the A_i's and H_i's are the area and height of the openings, respectively. For floor and ceiling vents, we will use H_i = ceiling height. This last assumption is an estimate which may warrant further investigation. When the floor vent or ceiling vent is the only vent opening this expression is not expected to be valid.

Using these definitions for A and H, the heat release rate becomes

$$Q = 1500\, A\sqrt{H} \qquad (\text{kW, m})$$

The fire will burn out after the total fuel load is consumed; that is, when the total heat released reaches the total combustion energy of the room contents.

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6.0 BARRIERS ON THE PIR

In the context of the Ship Fire Safety Engineering Method a barrier is any surface that separates two spaces and which will stop or delay ignition from one space to the other. Barriers may be penetrated or unpenetrated, combustible or non-combustible, load bearing or non-load bearing. In order to provide flexibility for the computer simulation analysis, a barrier may also be defined as a "zero strength" barrier. This concept is useful for segmenting large areas into zones for more detailed analysis. In this case, the barrier is an imaginary plane that may be located at natural fire breaks, such as aisles or non-combustible material locations. The concept is especially useful for shipboard analyses where spaces such as engine rooms may be two or three decks high. In these cases each level of the engine room is treated as a separate compartment connected to the next level with a "zero strength" barrier. It is also useful for expanded metal screening within spaces which subdivide larger spaces.

The fire resistive effectiveness of barriers are described by Tbar and the Dbar curves. These curves predict the capability of a barrier in preventing a small, hot spot ignition into the next space (Tbar failure) or a large, massive ignition into the space (Dbar failure). The effect on the room fire conditions for fire propagation are, of course, significantly different for the two situations.

The Tbar and Dbar descriptors are related to each other in the engineering method because together they may be used to describe the expected performance characteristics for any barrier. Each is evaluated by answering the question, what is the probability that the barrier will exhibit a Tbar (or Dbar) failure at a heat energy impact determined by the fire in the compartment less the heat which escaped from it.

The heat energy impact is the thermal heat flux to which the barrier is subjected during the fire. This heat flux may cause a small (Tbar) or a large (Dbar) failure as it reaches successively larger values. Usually, as the fire continues to burn, small, Tbar failures will grow into large, Dbar failures. If enough fuel is present, most barriers will fail eventually by a Dbar failure. The engineering method and the computer model integrate the expected behavior for each barrier.

The computer model is structured to use any heat release rate conditions identified by the engineer. At the present time, the heat energy impact release rate uses the conventional fuel load-heat energy release described by Ingberg (1.). This heat energy impact is used to relate the ASTM E-119 Fire Endurance Test (2) for barriers to fuel load quantification. Consequently, fire test data can be used as a base for selecting the Tbar and Dbar performance curves.

The ASTM E119 fire endurance test is a useful laboratory test to compare the fire resistance of different barrier assemblies. Failure conditions are described by collapse, or crack development, or thermal transmission (whichever occurs first) under conditions of a standard fire. Unfortunately, the test does not continue after an initial failure condition occurs, nor does it include such important, practical field conditions as penetrations or constructional support features. The engineering method extends the standard fire test into describing expected performance characteristics in practice. When available, ASTM E-119 test results are used as a starting base. When these results are not available, fire performance characteristics are based on small-scale parameter studies or other test performance. In any event, test or experiential results are translated into Tbar and Dbar values by engineering judgment.

For the PIR, 16 barrier materials were identified as shown in Table 6.1. There are four ceiling materials (C1-4), four floor materials (F1-4) and eight wall materials (W1-8). The physical properties which affect their fire resistance and thermal performance are also given.

The selection of the Tbar and Dbar values for the PIR was based on the following: (1) experience in selecting barrier values for building fire safety analyses; (2) study of the ASTM E-119 test protocol, its results, and analysis of the test in the open literature; (3) study of specific fire endurance test results for barriers expected to be used in the PIR (3, 4, 5, 6, 7); (4) experience in evaluating barriers for the POLAR SEA (WAGB-11) and in studying photographs of barriers in that vessel; (5) engineering judgment based on expected composite behavior of the barriers specified in the PIR. An integration of these factors became the basis for the selections. They are shown in Table 6.1 for ideally installed unpenetrated barriers.

To obtain Tbar and Dbar values for barriers in the as-installed condition the ideal values had to be de-rated. Again this was done using engineering judgment and results from previous experimental work. It took into account the doors and hatches and other penetrations anticipated for each barrier. The types of doors and hatches considered are listed in Table 6.2. The values assigned for each barrier enclosing a compartment are presented in the Barrier Fire Safety Summaries in Appendix N.

Another factor in flame movement analysis that is related to barrier performance is the percent residual heat transfer. When a barrier experiences a massive, Dbar, failure, some of the heat released by the first compartment will be transferred into the adjacent compartment there by increasing the heat energy impact on the barriers in the second compartment. In the case of a zero strength barrier, a substantial amount of heat transfer will occur. In the case of an open door, considerably less heat will be released into the adjacent room. The percentage heat transfer

TABLE 6.1

BARRIER MATERIALS & PROPERTIES

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Page # 1

ID thickness meters	MATERIAL DESCRIPTION density Kg/m3	spec_heat J/Kg.K	therm_cond W/M.K	max_Tbar value	max_Dbar value	% heat rel
C0	Zero strength overhead					
.000	0	0	0.00	0	0	100
C1	Aluminum grating					
.000	0	0	0.00	0	0	90
C2	Steel grating					
.000	0	0	0.00	0	0	90
C3	Steel deck					
.012	7840	500	45.30	10	100	5
C4	Steel overhead with poured floor or tile (1/4" thick)					
.019	7800	750	2.00	25	120	3
F0	Zero strength deck					
.000	0	0	0.00	0	0	100
F1	Aluminum grating					
.000	0	0	0.00	0	0	10
F2	Steel grating					
.000	0	0	0.00	0	0	10
F3	Steel deck					
.012	7840	500	45.30	25	300	5
F4	Steel deck with poured floor or tile (1/4" thick)					
.019	7800	750	2.00	75	340	3
W0	Zero strength bulkhead					
.000	0	0	0.00	0	0	100
W1	Expanded metal "screening"					
.000	0	0	0.00	0	0	80
W2	Nomex honeycomb core panel-plastic laminate both sides					
.017	48	1210	0.07	25	40	30
W3	Nomex honeycomb core panel-stainless steel both sides					
.017	50	1210	0.08	25	60	25
W4	Nomex honeycomb core panel-plastic laminate & thermal insulation					
.051	50	1210	0.04	40	40	30
W5	Steel joiner					
.006	7840	500	45.30	5	80	5
W6	Structural steel					
.010	7840	500	45.30	10	100	5
W7	Steel joiner with thermal insulation					
.051	7800	100	1.00	60	100	5
W8	Structural steel with thermal insulation					
.051	7800	100	1.00	80	100	5

TABLE 6.2

DOOR AND HATCH TYPES

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Page # 1

TYPE	DESCRIPTION	AREA (sq.ft.)
D1	Steel joiner door with louvers	16.25
D2	Steel joiner door	16.25
D3	Steel joiner door-insulated	16.25
D4	Watertight steel door	16.25
D5	Watertight steel door with automated closer	16.25
D6	Watertight steel door with automatic closer	16.25
D7	Open door way	16.25
D8	Steel joiner door with automatic closer (normally closed)	16.25
H1	Watertight steel hatch with scuttle (normally open)	16.25
H2	Watertight steel hatch with scuttle (normally closed)	16.25
H3	Watertight steel hatch (normally closed)	16.25
H4	Open hatchway	16.25

component identifies the percentage of the unburned fuel that is transferred to the adjacent compartment. This value was established for the PIR by engineering judgment, considering the fire conditions expected to be present at a Dbar failure. The values assigned for each barrier are also presented in Appendix N.

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7.0 ACTIVE FIRE PROTECTION ON PIR

Active fire protection on the PIR consists of fire detection, automated fire suppression systems, and manual fire fighting/damage control teams. The automated suppression involves fixed extinguishment systems activated by human means. Manual suppression involves fire extinguishment using hand hose lines with seawater alone or with AFFF as the extinguishing agent. Active fire protection systems being considered for the PIR are listed in Table 7.1. A listing of which systems are assigned to each compartment is presented in Appendix J, Assigned Fire Protection Systems.

The following sections will provide a detailed evaluation of these active systems. Alternatives and recommendations for improvements to these systems are presented in section 2.1.2. Following the detailed evaluation of systems, eight typical compartments are analyzed in detail.

The A-curve describes the expected capability of a specified automated system to extinguish a fire in a specific compartment. The evaluation depends upon two components. The first is the expected fire for the space being studied. This component evaluates the type, locations, heat release characteristics, and expected time for fire size development. The second component is the evaluation of the reliability of the fixed equipment and its capability of extinguishing an expected size fire upon activation. In the case of shipboard fires, stability and crew manning levels at sea or in port are incorporated into the analysis. Time is the parameter that links fire growth and suppression capabilities. Assumed design conditions involved both calm sea conditions and heavy seas causing substantial pitch and roll.

The automated systems considered for the PIR are discussed in section 7.3. The A-values were determined by first considering the intrinsic reliability of the system for the compartment and design conditions. The expected time-to-agent application was considered next. This incorporated the manning and detection system and the time to activate the system. This time was compared to an expected fire size based on reasonable fire scenarios for the fuels and functions of the spaces. The capability of the system to extinguish a fire of that size was the basis for the extinguishment capability component.

Evaluations for the reliability (i.e., agent application probability) and the design effectiveness of the systems for an expected fire size was based on engineering judgment. This judgment was based on discussions between Worcester Polytechnic Institute, Rolf Jensen & Associates, and Marine Fire and Safety Research Staff engineers.

TABLE 7.1

ACTIVE FIRE PROTECTION SYSTEMS
for
POLAR ICEBREAKER REPLACEMENT
(drawings dated 05/12/1987)

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Page # 1

CODE	PROTECTION DESCRIPTION
DETECTION:	
D%M	% Staffed-manual detection (%M)
DF	Flame detection system (UV or IR) (F)
DFT	Fixed temperature detection system (FT)
DI	Ionization smoke detection system (I)
DP	Photo electric smoke detection system (P)
DRR	Rate of temperature rise detection system (RR)
FIRST AID:	
F1211	Hand portable Halon 1211 fire extinguisher
F1301	Hand portable Halon fire extinguisher (1301)
FCO2	Hand portable carbon dioxide fire extinguisher
FMON	Hand portable monoammonium phosphate fire extinguisher
FPKP	Hand portable dry chemical fire extinguisher (PKP)
AUTOMATIC:	
A1301	Halon 1301 total flooding system - remotely actuated
AF	AFFF (3%) sprinkler system - remotely actuated
AFM	AFFF (3%) monitor - remotely controlled
APC	Aqueous potassium carbonate
AS	Seawater sprinkler system - remotely activated
MANUAL:	
M100	1 1/2" Seawater hand line with "all purpose nozzle" 100 ft.
M50	1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.
MF100	1 1/2" AFFF (3%) hand line with SFL variable nozzle 100 ft.
MF50	1 1/2" AFFF (3%) hand line with SFL variable nozzle 50 ft.
MHCO2	Carbon dioxide hand line
MHPKP	Dry chemical hand line

The M-values for manual suppression using hand lines were developed generally in a similar manner. First the reliability of the fire mains and delivery system was evaluated. Then, the capability of the fire fighting crew was evaluated for the type of fire expected. The fire type was based on reasonable scenarios for the fuel loading and the function of the space being considered.

Time again links the expected fire size with the agent application event. The time-to-agent application was estimated in large part on the fire drill on the POLAR SEA presented in Section 3.2. Detailed analysis of variations on the time line for fire fighting were compared with expected fire sizes in the fire scenarios considered. In addition, the protective equipment and procedures of the fire fighting team, as well as the expected compartment environmental conditions, were incorporated into the estimation of the probability of success of the manual fire fighting effort.

Shipboard fire fighting doctrine is important in evaluating the A- and M- values. Time is an important parameter in the common paths of fire growth and agent application. In those compartments where automated extinguishment is expected to be utilized before manual extinguishment, the fire size after hand lines finally are put into service is likely to be larger than can be extinguished effectively by hand. Shipboard fire fighting doctrine should be evaluated relative to effectiveness for the compartment being studied. In the case of the PIR, it was assumed that automated systems, where present, would be activated before manual fire fighting measures.

A- and M- values were determined as described above for the eight typical compartments evaluated in section 7.3. These values were then used as the basis to extrapolate A- and M- values for every compartment on the PIR to be considered in the flame movement analysis. The resulting values are presented in Appendix K, Effectiveness of Active Fire Protection, and used for the flame movement analysis presented in section 8.1.

7.1 FIRE DETECTION

Fire detection can be accomplished by people or by automatic detectors. Once detected the appropriate notification actions must take place. For manual detection this is accomplished orally while for automatic detection it is accomplished by alarms or indicator lights. This section will discuss fire detection for the PIR and will recommend automatic fire detection systems taking the anticipated manual fire detection probability into account. The resultant probability of detection will then be used in estimating the automated (A) and manual (M) fire protection system's effectiveness for purposes of the flame movement analysis in Section (8.1).

7.1.1 MANUAL FIRE DETECTION

Manual fire detection is only possible if people are available to sense a fire. This can happen if they are in the compartment where a fire is starting or if they are next to a compartment where a fire has developed to the point where it is giving signs outside of the compartment of origin. This analysis only considered the case where the compartment of fire origin was occupied at the time of the fire. Further it only considered the time that an occupant was awake and alert as revelant to fire detection. Estimates for the occupancy time were made with the assistance of a Coast Guard engineer who has seagoing experience. The estimates were then cross-checked with values reported in reference (1). Occupancy time was estimated for both at sea and in port situations. The results of these estimates are shown for each compartment in the Compartment and Barrier Fire Safety Summaries (Appendix N) in the Detection section.

7.1.2 AUTOMATIC - FIRE DETECTION AND ALARM SYSTEMS

Automatic fire detection is strongly recommended for inclusion in the specifications for the Polar Icebreaker Replacement (PIR) design. Early detection is essential for life safety. It also provides increased response time which is valuable in limiting property damage. This section will describe a rationale for determining which compartments should have fire detection, what types of detection should be used in each compartment, and the recommended functions that the detection system should perform. It will also reference a method to determine the number and location of detectors required to adequately cover a compartment.

AUTOMATIC FIRE DETECTION PRIORITY

The priority for compartments which require fire detection was determined as a function of:

Criticality of the Compartment (CC) - This was determined from information obtained in a meeting with Coast Guard Cutter designers, engineers and operators. It is the product of the unacceptable loss (area) and the threshold frequency for that loss as chosen in the meeting.

Expected Frequency of Established Burning (fEB)
This frequency was determined from information (1) based on Navy Safety Center statistics. Established Burning is the point in fire development where detection becomes likely.

Percentage of Time the Compartment is Occupied (%O)
This factor is a measure of whether a fire would be manually detected. It is based on the occupancy times developed for the manual fire detection (Section 7.1). The lesser of the "in port" and "at sea" times was used for the detection priority calculation as it would provide the case where manual detection was least likely.

The resultant detection priority (dP) was defined as:

$$dP = (fEB)((100-\%O)/100)/(CC)$$

This expression combines the qualitative factors which affect detection. The numerator is a measure of a fire being established but not detected by a member of the crew. Each factor is included in the expression in such a way as to increase or decrease the priority appropriately. Thus the resultant priority has no inherent meaning but is valuable to rank compartments relatively.

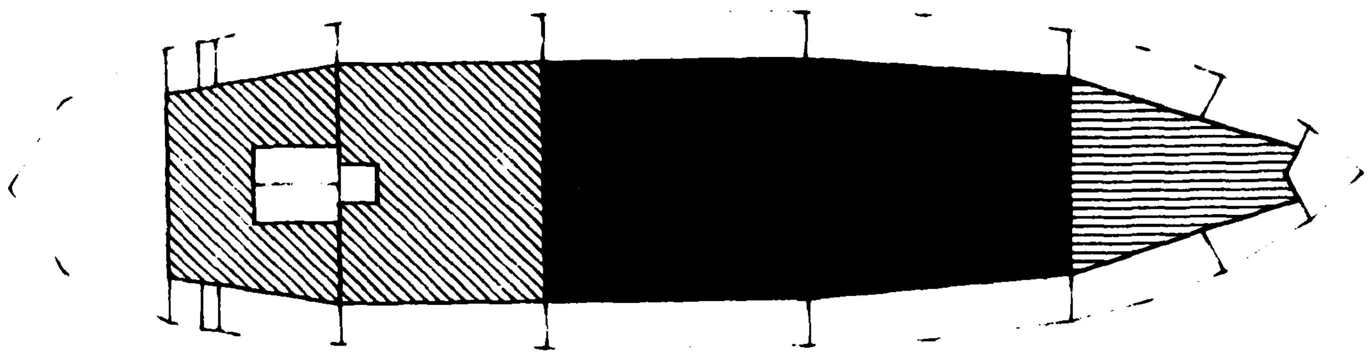
The results of detection priority determinations for the PIR are pictorally presented in Figure 7.1 (5 pages). This shows quite graphically how important detection is in the Main Engine Rooms

FIGURE 7.1: AUTOMATIC DETECTION PRIORITY for PIR COMPARTMENTS (5 pages)

* - These Spaces To Be Assigned Detection Independently

(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 08/12/1987
Thu Oct 29 09:27:05 1987



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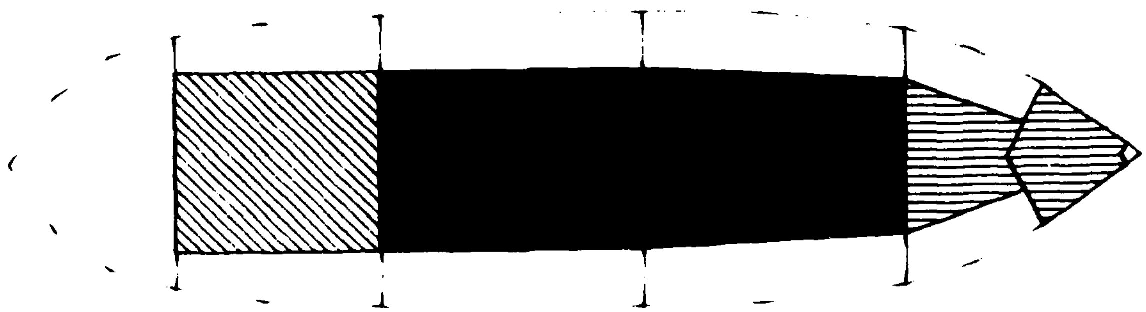

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FIGURE 7.1: AUTOMATIC DETECTION PRIORITY for PIR COMPARTMENTS (5 pages)

* - These Spaces To Be Assigned Detection Independently

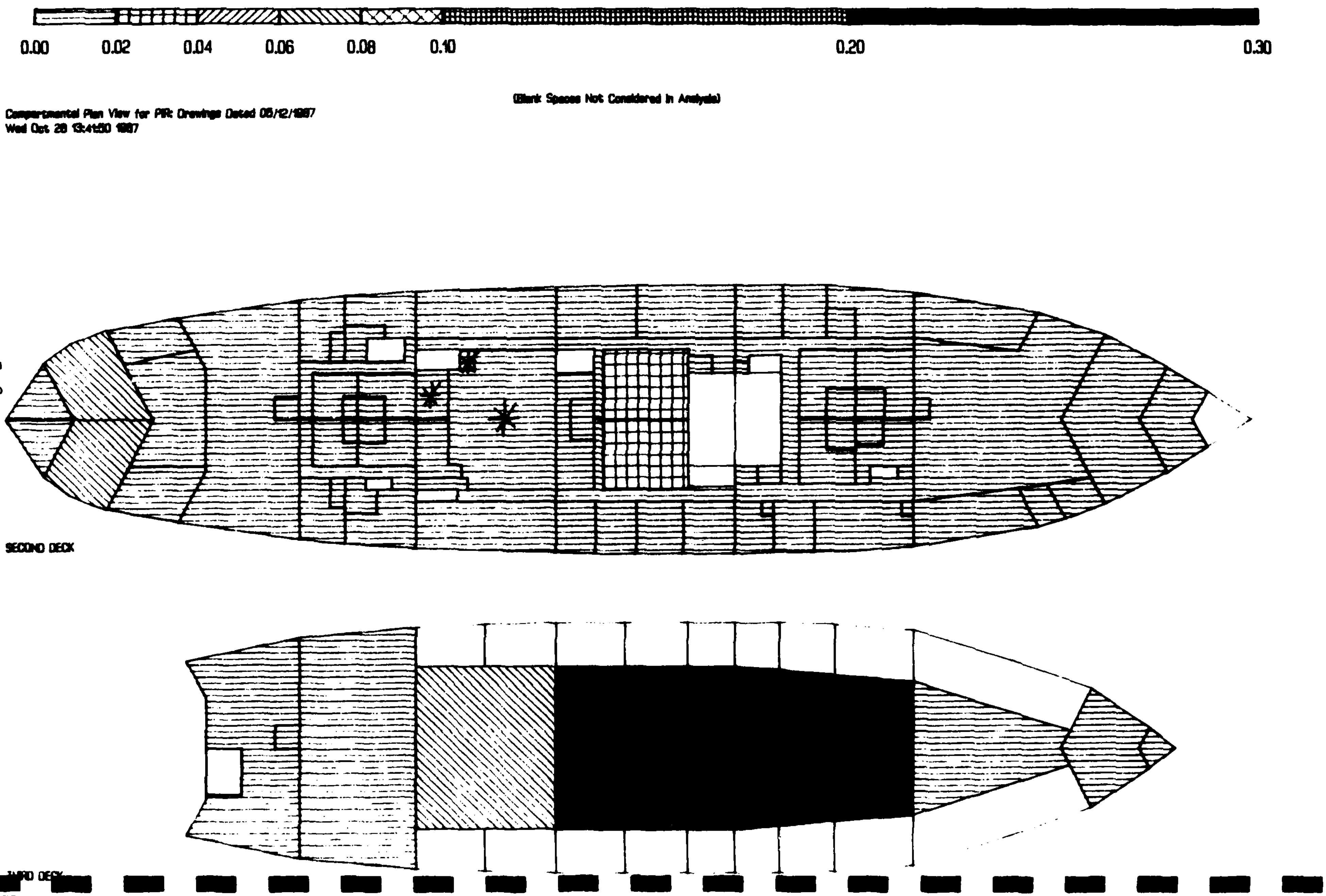


FIGURE 7.1: AUTOMATIC DETECTION PRIORITY for PIR COMPARTMENTS (5 pages)

* - These Spaces To Be Assigned Detection Independently

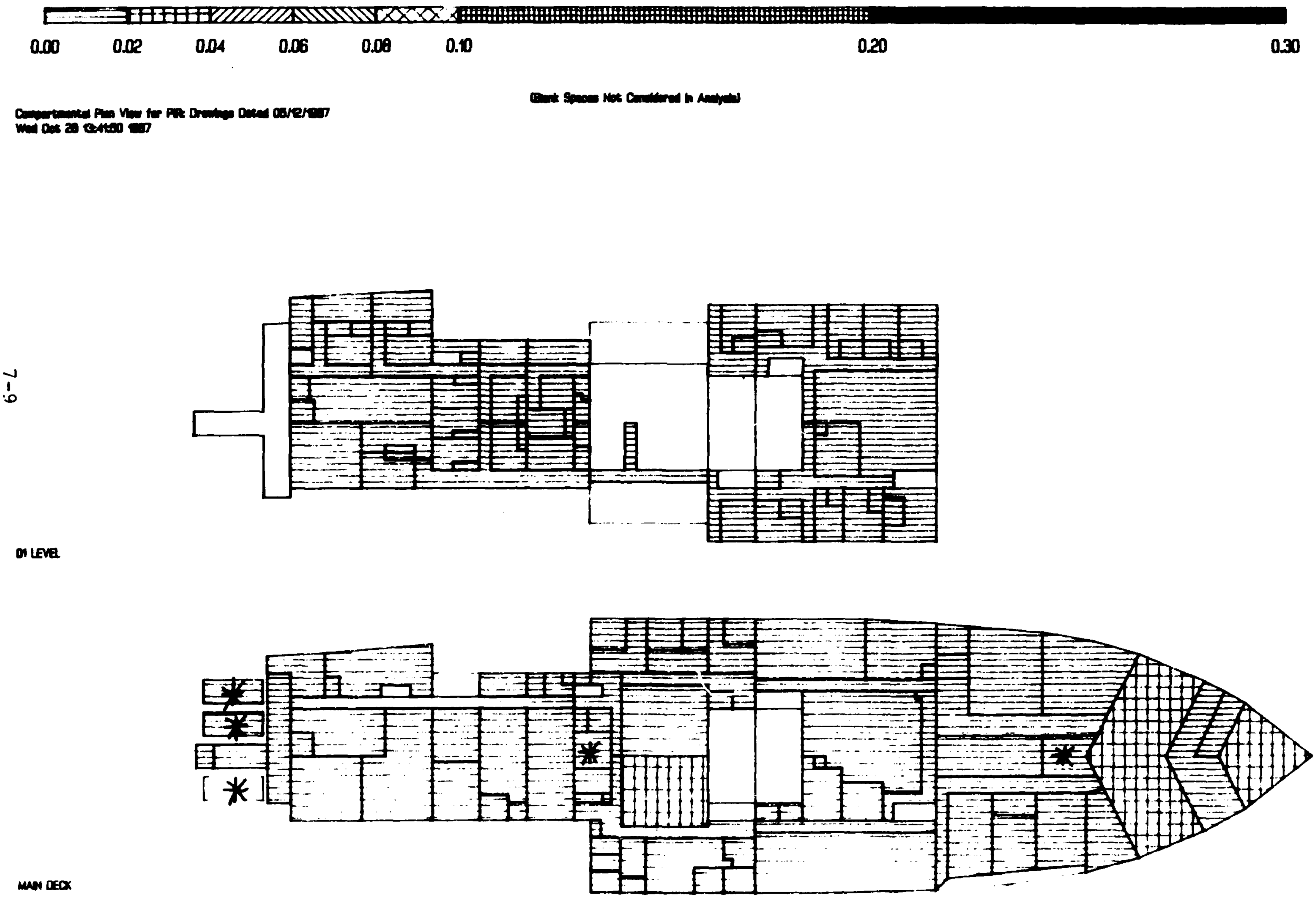
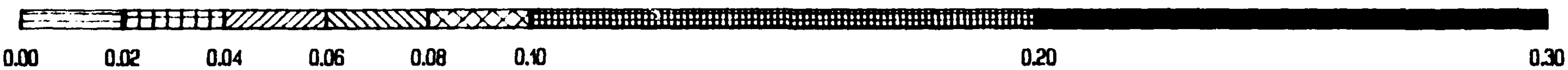


FIGURE 7.1: AUTOMATIC DETECTION PRIORITY for PIR COMPARTMENTS (5 pages)

* - These Spaces To Be Assigned Detection Independently



(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 06/12/1987
Wed Oct 28 13:41:50 1987

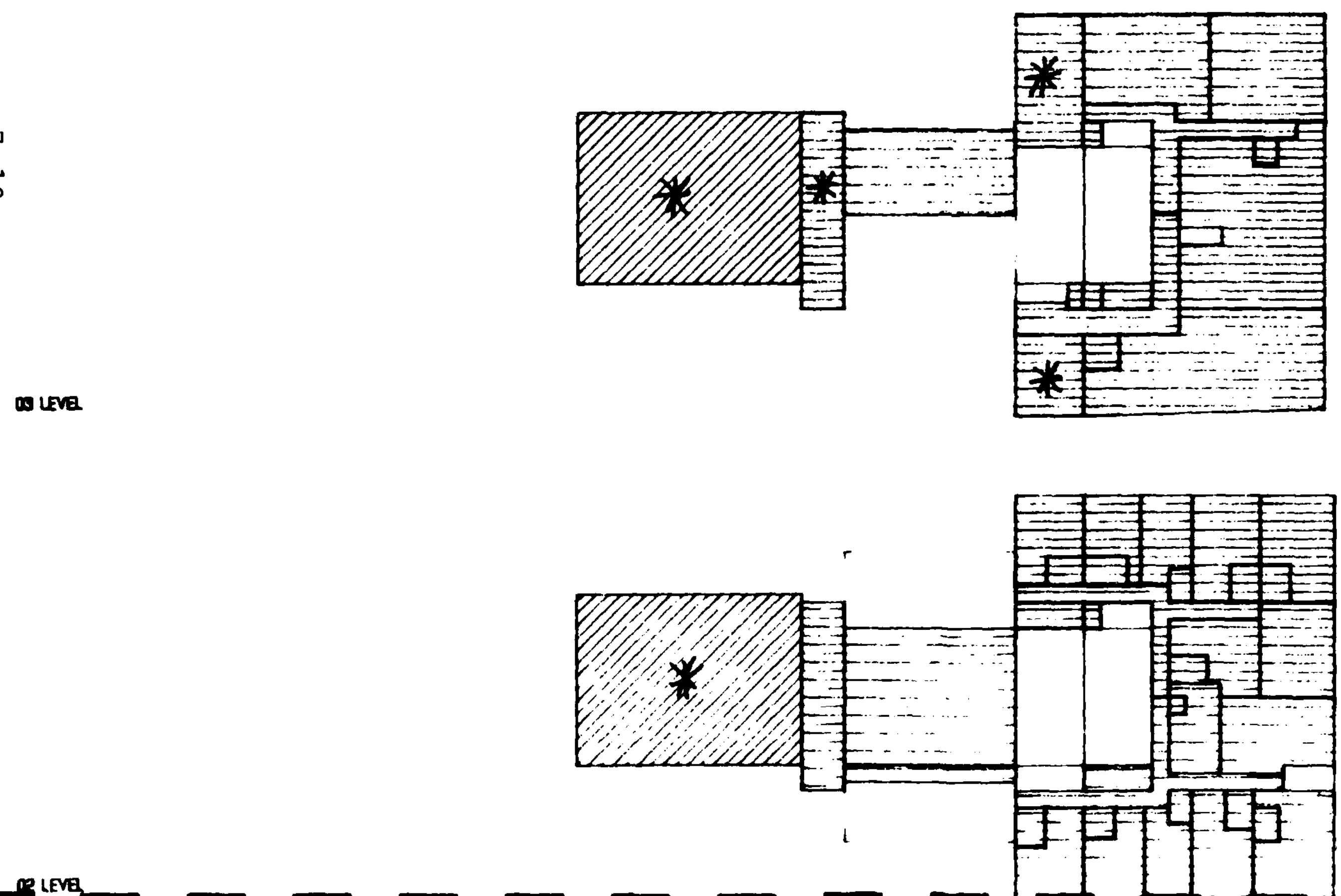
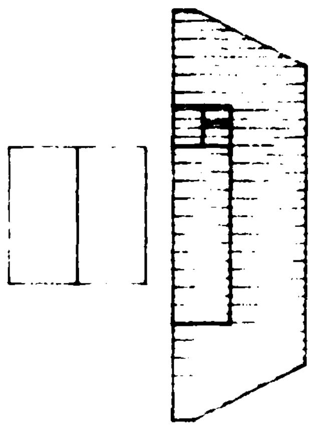


FIGURE 7.1: AUTOMATIC DETECTION PRIORITY for PIR COMPARTMENTS (5 pages)

* - These Spaces To Be Assigned Detection Independently

(Blank Spaces Not Considered In Analysis)

Compartmental Plan View for PIR: Drawings Dated 05/12/1987
Wed Oct 28 13:41:00 1987



04 LEVEL

and which compartments have lesser priorities. The priorities ("prior") are again shown in Appendix I, Fire Detection Priority and Recommendations, followed by the compartment identification and detection types recommended for it.

The detection requirements are prioritized so that a rational approach can be used in final design decisions. While all of the detection listed is recommended, cost or weight constraints may not permit it. In that case there are two approaches. One is to eliminate detection in lower priority compartments. The other is to eliminate one type of detection in a compartment which calls for more than one type. In this regard for accommodation and office spaces, it is recommended that ionization detection be eliminated when photoelectric detection is also called for because ionization detection has a higher false alarm history.

AUTOMATIC FIRE DETECTION SELECTION

There are five basic types of automatic fire detectors being considered for the PIR:

fixed temperature detection (FT),
rate of temperature rise detection (RR),
ionization smoke detection (I),
photo electric smoke detection (P), and
flame detection, ultraviolet or infrared (F).

Each of these detection types have their strengths and weaknesses for detecting different kinds of fires. Therefore, the appropriate detection type must be chosen for the anticipated fire scenario in each compartment. If more than one scenario is likely, then more than one type of detector may be required. Selection of detection types for each compartment on the PIR was based on the report "Shipboard Fire Detection System Selection and Installation Guidance" (2). This report is a result of the Navy's Fire Detection Program which began in the late 1970's. It is the most extensive evaluation of fire detection methods for ships conducted to date.

Detector selections were made by comparing compartment types on the PIR to those in the report and assigning the recommended detection type after checking for specific exclusions. For example, ionization detectors cannot be used in diesel engine rooms because submicron size particles can cause false alarms. Most compartments were adequately assigned detection in this manner (see Appendix I). A few special cases had to be handled independently as described below.

Fan Rooms - (03-218-0, 03-162-3, 03-162-2, 1-49-0, 2-343-1, and 2-262-2). While detection types are assigned in Table 1, these should be reconsidered on a case-by-case basis. Some fan rooms double for storage. All should be considered from the point of view of the high volume of air movement bringing in grease and dirt which can clog a detector.

Passageways - Fire detection in passageways is being debated in the Navy (3). The best estimate at this time is that ionization detectors should be installed on the centerline with a spacing greater than 16' but less than 30'. There should be at least one detector within each area where the overhead is subdivided by curtain plates or other continuous dividers which extend down from the ceiling by eight inches or more.

Stair Towers - Automatic fire detectors were not assigned to stair towers because there is very little if anything to burn in them; they were assumed to be surrounded by steel joiner bulkheads with self-closing steel doors and adjacent spaces will have detection.

Battery Room - (2-251-2) The PIR design calls for a battery room which is not addressed in the detection guidelines (2 and 3). Photoelectric and ionization detectors as found in storage areas are recommended. In addition hydrogen detection is recommended if battery charging is anticipated in this space.

Small Arms Stow and Repair - (1-210-0) The detection priority calculated as zero for this space because there was no frequency of established burning data to enter. The actual priority should be quite high because of the ammunition which can cook-off in this space. The four types of detection are recommended because of this cook-off threat.

Portable Vans - (1-328-1, 1-328-2, and 1-328-4) Again the detection priority calculated as zero for these spaces because there was no frequency of established burning data to enter. It is recommended that they be treated as storage spaces or science spaces depending on their intended use. Their destruction by fire poses little threat to the ship, but the property so destroyed could be quite valuable. The detection should be tied into the general ship fire detection and alarm system so that damage control teams will be aware of developing fires.

Engineering Control Center - (2-223-0) The detection priority calculated as zero for the ECC because it was assumed to be occuppied by an alert watch 100% of the time, both while at sea or in port. It is recommended that detection in cabinets which house critical control systems be considered.

Elevators and Hoists - (1-146-1, 1-169-2, 02-138-1, and 1-311-2) Detection is recommended in these spaces. They are at the top of elevator or hoist trunks which can act as chimneys. Early detection in these spaces may indicate a fire in the trunk or in spaces served by it.

Hangar - (02-228-0 and 03-228-0) There is evidence that electromagnetic interference during helicopter operation causes some photoelectrical detectors to give false alarms (3). Further information should be obtained before final detector selections are made for these spaces.

FIRE DETECTOR LOCATIONS AND QUANTITIES

Section III of reference (2) describes how to determine the detector quantities and detector locations for each compartment. Generally smoke detectors should be required to cover no more than 250 square feet of area for compartments with deck-to-deck heights less than 16 feet. Spaces with heights greater than 16 feet should be considered for detectors at intermediate levels as well as on the overhead. Spaces of this type on the PIR include Engine Room No. 1, Engine Room No. 2, Motor Room, Emergency/Harbor Generator Room, Boiler Room(s), Hangar, and Vestibule. When ionization and photoelectric detectors are called for in the same compartment, they should not be installed in the same locations.

DETECTION SYSTEM RECOMMENDATIONS

The Sponsor's Requirements Document for the PIR (4) calls for fire alarms on the Bridge and in the Engineering Control Center. To meet this requirement and provide improved response it is recommended that the main detection system annunciation panel with all features be located in the ECC, that a repeater system of most supervisory functions be located in Damage Control Central, and that a remote alarming system be located on the bridge. In addition it is recommended that the fire detection system provide the following features:

Local Alarm - Local alarm is a primary consideration for life safety. It also may provide the notification necessary for local personnel to take actions which mitigate the effects of the fire.

Fire Location - Currently available supervised fire detection systems are capable of identifying which detectors are alarming at any time. With this information and plans of detector locations, the compartment and area of origin of the fire can be identified easily. Further, the spread of the fire can be followed by watching the system panel. This is a tremendous aid in conducting damage control operations.

Detector Status - Current systems can check for and report individual detector malfunctions, open circuits, and in some cases false alarms. These features help to eliminate the possibility of relying on detectors which are not working.

Automatic Actuation - While it is generally the Coast Guard's policy to manually actuate various fire protection systems there are some cases where automatic actuation could be used without contradicting the intent of the policy. One

example is the automatic start of the fire pumps. Fire pumps are not normally operating on Coast Guard Cutters. Upon proper notification the ECC watch starts them. During a fire situation there can be a lot of confusion. Starting of the fire pumps could be easily overlooked or the starting systems might malfunction. If the detection system were set up to automatically actuate them upon detection, the fire main would be up to pressure when required. If the detection turned out to be a false alarm, no harm would be done. Another system which could be automatically actuated is the AFFF proportioning system.

Additional desirable features which should be specified are:

1. Alarm initiating circuits and signaling circuits (if a multiplex system is used) should be wired using closed loops so that the circuit can operate over a single break or open. This type of circuit is commonly referred to as a Class "A" circuit, an obsolete term, formerly used in the NFPA 72 Series Standards. The outgoing and return legs of the circuit loop should be routed so that a single fire will not expose both circuit legs. This is to help ensure the integrity of the system, particularly during a fire condition.

2. Each circuit should be electrically supervised with trouble signals annunciated in the ECC and DCC. The system should supervise all input and output circuits, all power supplies, and all remote annunciating devices. This is to help ensure that the systems will be operable during a fire condition.

3. Each compartment should be annunciated as a separate zone, to assist responding fire fighting personnel in identifying the fire alarm location.

4. When multiple detector types are used within a compartment, each detector type should be on a separate zone. This will help identify the source and cause of unwanted alarms.

5. Each protected compartment entry point should have a remote annunciator light indicating that a detector within that compartment has operated. When multiple zones are provided, there should be an indicator light for each zone. This is to alert personnel to the potential fire condition prior to their entry into the compartment. It is also to assist responding fire fighting personnel in their assessment of the fire situation.

6. Each detector should "latch" into alarm, requiring System reset at the main control panel prior to clearing the alarm condition. When several detectors are installed within a compartment and when detectors are concealed from view, they should be provided with either a light at each detector or a

remote light at an observable location, as appropriate. This is to help locate an operating detector when no fire condition is apparent. Such an alarm could either be caused by a malfunctioning detector or by a fire condition which is not readily observed. In either case, knowing which detector operated will help to identify the problem, allowing the system to be restored to service sooner.

7. The fire detection and alarm system should be provided with a secondary power supply. If the secondary supply is a battery, it should be capable of operating the system for 24 hours. If the secondary supply is an emergency generator, a battery supply, capable of operating the system for 4 hours, should also be provided so that alarm signals will not be lost during the transition from the primary to the secondary supply. The power supply should be located so that a single fire will not affect both primary and secondary power supply.

8. The system should be provided with a printer to make a permanent record of all system activity. This is to help locate possible system problems and to help ensure proper system maintenance.

9. The system should have every circuit and device tested, both initially and on a regular basis, to ensure that it is operational when installed and is maintained operational. Each device should be operated and tested for supervision, and each circuit should be tested for supervision of conductor-to-conductor shorts, opens, and ground faults.

10. Provision should be provided to communicate between the responding fire fighter personnel and the ECC and DCC. This can be through a ship telephone system or through a dedicated fire fighters' telephone system. The ship's telephone system should be adequate for this purpose, if a telephone is provided within the protected compartments.

The detection system to be supplied under military specification to the Navy (reference 5) is recommended for consideration. This system has been designed, tested and evaluated not only for its fire detection performance characteristics but also for characteristics such as shock, vibration and humidity which will determine its long-term survival in a shipboard environment. It will be obtainable through the Federal Stock system. Since it will be used on many Navy ships, parts will be guaranteed for a long time. One principal disadvantage is that it will probably be more expensive than commercial detection systems. It is currently undergoing an operational evaluation which G-ENE should review. Following that a Coast Guard operational evaluation might be in order.

7.2 AUTOMATED AND MANUAL FIRE SUPPRESSION SYSTEMS

Six fire suppression systems have been considered in this analysis. Five of these systems use seawater as the basic suppression agent while the sixth system uses Halon 1301. The six systems are:

1. Hand hose lines using 1-1/2 inch hose with the Coast Guard "all purpose" nozzle. Sea water is the suppression agent.

2. Hand hose line using 1-1/2 inch hose with AFFF as the suppression agent and a "SFL variable nozzle."

3. Sea water sprinkler system - manually activated.

4. AFFF sprinkler system - manually activated.

5. AFFF monitor nozzle - remotely controlled and manually operated.

6. Halon 1301 total flooding, manually activated system.

The common elements to all systems include a fire detection and alarm system with remote annunciation and remotely controlled system operation and supervision.

The common elements to all seawater-based fire suppression systems include the seawater pumping system and the seawater fire main. The common elements to all AFFF systems also include the AFFF proportioning equipment and the AFFF fire main.

7.2.1 REMOTELY CONTROLLED SYSTEM OPERATION/SUPERVISION

Remotely operated systems are currently specified for use in four of the eight compartments under consideration. The fire pumps are also specified to have remote operating capability.

As a general premise, operation of the manually operated fixed suppression systems should be based on the fire fighters' judgment at the fire scene rather than automatically or remotely operated. Each of the fixed suppression systems under consideration has a potential of causing an increased loss either due to suppression system agent damage or due to the cost of recharging the system. These systems should not be operated unless needed for fire control, as judged by on-site personnel.

Electrical operation and supervision of remote devices should be accomplished using the fire detection and alarm system. Desirable features which should be specified are:

1. Remote operating circuits, such as valve operation and pump start/stop circuits, should be Class "A" circuits, as previously described. The circuits should transmit data-based commands rather than using operation of dry contacts for a command signal. This is to prevent change of status of the operated device in the event of circuit failure. For example, if a command were given to stop a fire pump by closing a set of normally open dry contacts, fire damage to that control circuit could cause a conductor-to-conductor short, giving the same stop command as closing the dry contacts. If a data base command is given, such a short would be seen as a trouble signal rather than as a stop command.

2. All remote operating circuits should be arranged so that loss of power to a circuit will not cause a change in status of the operated device nor prevent its being manually operated.

3. All operating circuits should be arranged so that attempted operation at two locations will not interfere with operation of the device. Such attempted operation at both the ECC and DCC should not cause a loss of signal or a garbled signal to the device.

4. Status of all operated devices should be indicated at the remote operating panels in the ECC and DCC. Status indicating circuits can be Class "B" circuits, supervised with an end-of-line resistor, rather than Class "A" circuits. A break or open in such a circuit will cause a trouble signal, requiring circuit repair. It will not allow transmitting a signal over the break or open. If such a circuit is damaged during a fire, the operator in the ECC or DCC can still operate remote devices, but will not have verification of the device status.

7.2.2 SEAWATER PUMPING SYSTEM

SYSTEM DESCRIPTION

Current specifications call for a seawater pumping system. System features are:

1. Three - 1,000 gpm at 145 psi manually started combination fire and flushing pumps will be provided. One pump is to be located in each engine room and one pump in the motor room.

2. The seawater suction supply is to be from the sea chest serving the associated compartment. Each pump will have a separate sea chest suction supply.

3. Each pump suction line and pump discharge line is to be provided with a shutoff valve capable of being remotely operated from the ECC or DCC. Each of the valves is to be capable of being manually operated at the valve location, overriding the remote operator feature.

4. Each suction supply line is to be provided with a single suction strainer.

5. The fire pump discharge line is to be provided with a discharge check valve. We assume that this valve will be located between the fire pump discharge flange and the discharge line shutoff valve so that the check valve can be serviced without taking the fire main out of service.

6. A recirculating relief valve to allow cooling water to pass through the fire pump under a churn condition.

Additional desirable features which should be specified are:

7. A minimum-run period timer to protect the pump and controller from a series of rapid start/stop commands which could cause damage to the pump motor or controller.

8. The fire pump power supply status and pump operating status be supervised both in the ECC and DCC so that personnel at those locations know the condition of the fire pump power availability and the fire pump operating status.

9. The fire pump suction and discharge valve position also be supervised in the ECC and DCC so that personnel know the status of the water supply control valves which isolate each fire pump.

10. The fire pump power supply cables be protected from the power supply source to the fire pump control panel and from the fire pump control panel to the pump motor so that a

single fire will not endanger the power supply to more than one fire pump. Protection could be in the form of separately routed cables, protection of the cable with a suitable fireproofing material or use of a cable which can tolerate exposure to fire, such as a mineral insulated (MI) cable.

11. The power supply for each fire pump be arranged so that a single fire will not endanger the power source to more than one fire pump. This will require a separate power supply source for each fire pump.

12. Remote fire pump operating controls be arranged so that a single fire will not damage the controls from both the ECC and the DCC. If the controls from either location are damaged, the damaged controls should not interfere with operation of the fire pump from the other location or at the fire pump control panel. The damaged controls should not cause a change in fire pump status. Use of a Class "A" circuit and data-based commands can accomplish this objective, as previously discussed.

13. The remote controls for the fire pump isolating valves be arranged in the same manner as the fire pump operating controls so that a single fire will not affect the ability to operate valves from both the ECC and the DCC. Damage to a control circuit should not cause loss of the ability to operate the valve from other control locations, nor should it cause a change in the valve status.

DISCUSSION

The proposed fire pump arrangement provides a dual source water supply for the fire suppression systems serving the engine compartments and the motor compartment. This assumes that the fire pump located in an engine or motor compartment is unavailable for service if a fire occurs in that compartment. The other two fire pumps would need to serve the suppression systems.

This arrangement provides a three-source water supply for the fire suppression systems in other areas of the ship.

Several potential problems need to be addressed in the design of the sea chest seawater inlets. The inlets should be designed so that:

1. Bottom sediment is not drawn into a sea chest when the ship is operating in shallow water or when it is docked.

2. Surface debris is not drawn into a sea chest.

3. The sea chest inlets remain submerged during the maximum ship roll and when the ship is breaking ice.

4. It is not possible to draw air into a chest and lose the fire pump prime when the ship is in a heavy sea or when it is breaking ice.

Provision is needed to bypass the fire pump suction line strainer, allowing the pump to remain in service, during the strainer cleaning operation. As an alternative, a dual strainer arrangement could be provided so that the pump could remain in service while one strainer is cleaned, being served through the other strainer.

Use of the fire pumps as both fire pumps and flushing water supply pumps will cause regular operation of the suction and discharge line valves to reduce the probability of corrosion to encrustation on the valve moving surfaces. This is an advantage of using the pumps on a regular basis, assuming that they are used in a rotating manner so that all pumps receive equal service time.

The fire pumps should be operated at full flow capacity on a regular basis to flush the suction and discharge lines of debris and marine growth. Inspection ports should be provided so that the interior condition of the suction and discharge lines can be observed to determine if there is a need for mechanical cleaning.

We assume that the fire pump and fire pump motor will have grease-lubricated bearings as is the case for conventional fire pumps. We also assume that the fire pumps will be provided with water-lubricated shaft packing. Inspection of the shaft packing and the water lubricating lines should be a part of the regular fire pump test/maintenance program.

The fire pump operating controls and the fire pump suction and discharge isolating valve operating controls should be arranged so that the valves must be open before the fire pump can be started. An optional approach would be to provide specific operating instructions at the remote operating locations so that operating personnel open the valves before the fire pump is started. Interlocks on the controls can be used to ensure a proper operating sequence, but they present a potential failure point and a complication of the operating controls. Operating instructions, if followed, can accomplish the same function.

The strengths and weaknesses of the seawater pumping system are summarized as follows:

SEA WATER PUMPING SYSTEM

STRENGTHS

1. Multiple source water supply - single fire should not affect more than one of the three water supply sources.

2. Pump pressure and volume should exceed that required by the hydraulically designed sprinkler systems and hose lines in any compartment. Water supply requirements of NFPA Standards 13 (Automatic Sprinklers) and 14 (Standpipe and Hose) are met or exceeded by each pump.

3. Regular use of the fire pumps will help keep discharge lines clean and valves in an operable condition. This should help to offset the related weakness of piping obstruction or corrosion caused by use of seawater.

WEAKNESSES

1. Fire pump may be out of service during strainer cleaning.

2. Fire pump suction supply may be affected by sediment, surface debris, heavy seas, or icebreaking operations.

3. Marine growth or corrosion caused by use of seawater may obstruct suction and discharge lines, packing gland cooling line, pump impeller, and water supply control valves.

4. Remote operation of the fire pump can occur while suction and discharge valves are closed. This will prevent water from entering the fire main and may cause damage to pump shaft and impeller.

7.2.3 SEAWATER FIRE MAIN

SYSTEM DESCRIPTION

The seawater fire main, which distributes the water received from the three fire pumps throughout the ship, will be a horizontal, looped main at the passageway overhead on the second deck. The size of the main is not stated. It is assumed that because 1,000 gpm pumps are used, that the main will be at least 6 inches in diameter.

The seawater fire main is to be a "dry" main. This means that it will not be pressurized by the fire pumps on a regular basis, but it will not be drained. It will be maintained in a non-pressurized, flooded condition. Each time the fire pumps start, they will pressurize the main with fresh seawater, replacing any which has leaked from the main since the last time the pumps were in operation.

The seawater fire main will supply:

1. Fire protection water to the sprinkler systems, foam proportioning equipment, and hand hose fire plugs.

2. Auxiliary, emergency water to the seawater cooling system.

3. Nuclear, biological, and chemical (NBC) washdown system.

4. Sewage tank flushing.

5. Anchor washdown system.

Sectional valves should be provided in the main so that a broken or damaged section can be isolated. These valves should be supervised at the ECC and DCC, but do not need to be remotely operated. A single break will remove those sprinkler systems and fire plugs between the sectional valves from service. Sprinkler systems can be maintained in service if they are provided with a fire hose connection as an alternative water supply source. Hoses could be laid between the connection and an in-service fire plug, supplying the sprinklers around the broken fire main through the hose lines.

DISCUSSION

The seawater fire main is not monitored to verify its integrity. If an open fire plug or a broken pipe occurs, it would not be detected until a fire pump is started and a subsequent leak identified.

There is the possibility of air entering the main as water is lost through leaks which may occur at valves or fittings. Presence of air in the main could create a hazard for fire fighters using a hand hose line.

Because fresh salt water will enter the main each time it is used to flush a sewage tank or wash an anchor, the oxygen content of the water will probably be high, increasing the possibility of corrosion and marine growth within the main. For this reason, access ports should be provided to inspect the main, the main should be regularly flushed under high volume flow rate conditions to help clean the pipe, and all valves serving sprinklers, hose lines, and AFFF systems should be operated regularly. This should be a part of a regular fire protection equipment preventive maintenance program.

The seawater fire main strengths and weaknesses are summarized as follows:

SEAWATER FIRE MAIN

STRENGTHS

1. Looped main provides improved hydraulic supply capability over an end feed main.

2. Some degree of protection can be provided in event of main break if sectional valves are used. It is possible to have a main break and still supply all sprinkler systems if fire hose connections are provided on the sprinkler systems.

WEAKNESSES

1. Main integrity is not monitored. Undetected leak or break could occur.

2. Air could enter main, endangering fire hose crews.

3. Corrosion or marine growth could be a problem, as previously discussed under fire pumps.

7.2.4 AFFF PROPORTIONING EQUIPMENT

SYSTEM DESCRIPTION

Current specifications call for two, 500 gpm balanced pressure pump proportioners with 225 gallons of AFFF, 3 percent concentrate storage. Each proportioner will be at a different location. The proportioner discharge piping will be cross-connected with a normally closed valve separating the systems. One proportioner will serve the hangar area, the other proportioner will serve the machinery spaces. The proportioners will supply AFFF sprinkler systems and the AFFF hand hose lines.

A desirable feature which should be specified for the AFFF proportioning equipment is to provide a fire main sectional valve between the two proportioner connections to the fire main. If this is done, loss of one section of the fire main would not take both proportioners out of service.

DISCUSSION

This proportioning arrangement requires four normally closed valves which need to be opened before the equipment can produce a foam solution. Three valves are located in the concentrate and proportioning equipment (two in the supply line and one in the return line). One valve is located in the main water supply line. Failure to open any of the three valves in the foam proportioning equipment will prevent a proper foam concentrate mix from occurring. Seawater with an improper foam concentrate mix will be provided to the AFFF main and AFFF systems, as long as the main seawater control valve opens properly. Should that valve fail to open, the systems will be out of service.

The foam pump must be arranged to start after the four valves are open and after at least one fire pump has started and provided seawater to the proportioning equipment.

Control of the foam proportioning equipment and valves is to occur both at the ECC and DCC along with local control provided at the proportioning equipment. As in the case of the fire pumps, the control circuits should be routed so that a single fire will not disrupt operation of both foam proportioning systems.

The foam pump power supply should be arranged in the same manner as the fire pump power supply relative to protecting the cables, and arranging the power supply so that each foam proportioner pump is supplied from a separate power source. A backup power supply should be provided because there are no redundant foam proportioning pumps, as there are redundant fire pumps.

The status of the foam proportioning equipment power supplies, foam pump operating mode, and proportioner control valves should

be monitored both at the ECC and DCC, in a fashion similar to the fire pump and fire pump control valve monitoring.

The 225 gallons of foam concentrate at each foam proportioning station appears to be insufficient, considering the engine room sprinkler and bilge sprinkler operating requirements. This should be verified. A concentrate tank of this size would be adequate if provision is made for additional foam concentrate to be added to it while the system is operating.

The foam proportioner must be able to adequately proportion foam solution over the range of individual demands served by that equipment. The minimum demand appears to be that of a single hose line, while the maximum demand would be that caused by operating the engine room overhead and bilge sprinklers simultaneously with a hand hose line. The proportioner must be able to produce an adequate foam solution mix over this entire range of flow rate demand. The proportioners presently contemplated apparently can meet these flow requirements.

The minimum volume of foam concentrate available to the foam concentrate pump needs to be determined under maximum ship roll or when the ship is breaking ice. The foam concentrate pump is a positive displacement, self-priming, pump. It will probably not be affected significantly by air entering the suction line if the ship is unstable due to a heavy sea or icebreaking operations.

The effect of marine growth and corrosion on the foam proportioning equipment must be considered. The seawater supply line should be provided with a dual strainer arrangement or a strainer bypass as suggested for the fire pump suction line.

The proportioning equipment should be inspected as a part of the regular fire protection equipment maintenance program to identify marine growth or corrosion within the proportioning venturi. Should such growth or corrosion occur, it should be removed as it could have an impact on the foam solution mix and the flow rate through the foam proportioner.

Use of 1 percent AFFF concentrate would reduce the size of the foam proportioner pump and the volume of foam concentrate needed to 1/3 of that needed for a 3 percent solution.

The 1 percent AFFF foam concentrate is produced by three of the eleven manufacturers of AFFF foam concentrate listed in the January 1987 Underwriters Laboratories, Inc., Fire Protection Equipment Directory. Those three manufacturers are Ansul, 3M, and National Foam. None of the international manufacturers listed presently produce UL listed, 1 percent AFFF concentrate. It is not known if 1 percent AFFF concentrate is or can be as readily available on a world-wide basis as 3 percent AFFF concentrate.

Should 3 percent concentrate be used in a system designed for a 1 percent concentrate, the fire fighting effectiveness of the foam solution is expected to be significantly reduced. Inadvertent resupply with available 3 percent concentrate, should 1 percent concentrate not be available, could seriously affect the fire fighting capability provided by the foam systems.

The advantage of 1 percent concentrate versus 3 percent concentrate appears to lie in the required volume of concentrate storage (75 gallons versus 225 gallons per proportioner) and the size of the proportioner pump (5 gpm versus 15 gpm for a 500 gpm proportioner). This advantage does not appear to offset the potential disadvantage of inadvertent refilling of the system with 3 percent concentrate and the negative effect on the fire fighting ability of the foam systems.

The AFFF proportioning equipment strengths and weaknesses are summarized as follows:

AFFF PROPORTIONING EQUIPMENT

STRENGTHS

1. Redundant foam supply is available by opening the discharge cross connection valve.

WEAKNESSES

1. The proportioning equipment and concentrate storage appears to be undersized for the demand.

2. Four normally closed valves must be opened for the proportioner to work properly.

3. A single foam proportioner pump is provided for each proportioner. That pump needs backup power.

4. Marine growth or corrosion could adversely affect the foam proportioner.

7.2.5 AFFF FIRE MAIN

SYSTEM DESCRIPTION

Two AFFF fire mains, one served by each proportioner, are to be provided. The mains are to be cross-connected with a normally closed valve so that in the event of an emergency, either proportioner can serve either main. Remote operation of this valve will be provided at the ECC and DCC in a manner similar to the remote operation for the AFFF proportioner system valves.

The AFFF main size is not given. It is assumed that it will be hydraulically sized to accommodate the maximum system flow rate.

The AFFF supply mains will provide foam solution to hand hose lines and sprinkler systems in the helicopter hangar (supplied by one main and proportioner) and in the engineering spaces and bilges (supplied by the other main and proportioner).

The AFFF main will be normally shut off, consistent with the proportioner manufacturer's recommendations.

Not knowing the size and length of the main, the time needed to fill the main with fresh foam solution to the foam systems cannot be determined. However, because the foam systems will be manually operated, this time factor is not as critical as it would be if the systems were to be automatically operated.

DISCUSSION

As in the case of the "dry" seawater fire main, the AFFF main will not have its integrity monitored if it is maintained in a dry, unpressurized condition.

This main will need to be drained and flushed with fresh water after the system operates to reduce the corrosive effects of the salt water foam solution. If salt water foam solution is allowed to remain in the piping, it can be expected to deteriorate rapidly. After the system has been flushed with fresh water, it should be refilled with fresh water and provided with a pressure maintenance jockey pump with the pressure supervised at the ECC and DCC in a manner similar to the supervision on the seawater fire main. The purpose of the jockey pump pressurization will be the same as for the seawater fire main.

The cross-connection control valve needs to be operated regularly through a full operating cycle to reduce corrosion or marine growth on the moving parts and to ensure that it remains in an operable condition.

Strength and weaknesses of the AFFF fire main are summarized as follows:

AFFF FIRE MAIN

STRENGTHS

1. Cross connection between both mains provides some degree of redundancy.

WEAKNESSES

1. Main integrity is not monitored, undetected leak or break could occur.

2. Air could enter main, endangering fire hose crews.

3. Corrosion or marine growth could be a problem.

7.2.6 <u>SEAWATER HAND HOSE LINES</u>

SYSTEM DESCRIPTION

Seawater hand hose lines are to be provided, supplied through a 2-1/2 inch fire plug with a double-gated wye, connected to the seawater fire main. The double gated wye provides two 1-1/2 inch outlets with a flow rate of 50 to 90 gpm per outlet, depending upon the hose nozzle setting and length of hose used.

The Coast Guard general purpose nozzle which will be used on the 1-1/2 inch hand hose line has three settings, (straight stream, narrow fog and wide fog), with a capability of passing a 1/4-inch diameter particle. Strainers are not provided at the fire plugs. The fire pump suction strainer is to remove larger particles.

The fire plugs will be served by a normally open valve at the seawater fire main connection. This valve should be supervised at the ECC and DCC. It does not need to be remotely operated. The fire plug valve will be normally closed and provided with a remote, mechanical operator if the fire plug is in a location exposed to the weather.

DISCUSSION

The procedure for use of hand hose lines is to have two fire fighting teams attack the fire, the first advancing to fight the fire with one hose, the second covering the first team with a water shield from the second hose.

Adequate fire plugs, hose, and nozzles are provided throughout the ship.

The effectiveness of the fire fighting team is a function of the fire fighters' training and sea conditions as they affect the ship's stability and the stability of the working platform for the fire fighters.

Strengths and weaknesses of the seawater hand hose lines are summarized as follows:

SEA WATER HAND HOSE LINES

STRENGTHS

1. Adequate water supply for small to moderate size compartment fires is provided. Water supply meets or exceeds NFPA Standard 13 and 14 criteria for 1-1/2 inch hose lines.

2. Variable pattern nozzle allows fire fighting crews an option in terms of attack tactics. This may increase the fire fighting effectiveness.

WEAKNESSES

1. Training and technique are important. An adequate water supply can help compensate for operator technique.

7.2.7 SEAWATER SPRINKLER SYSTEMS

SYSTEM DESCRIPTION

The seawater sprinkler systems are to be installed at a density of 0.20 gpm per square foot over the compartment area. Open sprinklers are to be used in the cargo hold areas. The systems are to be manually operated with remote control capability provided at the ECC and DCC along with local operating capability at the system control valve near the protected compartment. A valve will also be provided at the connection to the seawater fire main. Both valves should be supervised at the ECC and DCC, but only the system control valve need be remotely operated.

DISCUSSION

Control of the sprinkler system valve from the ECC and DCC should be arranged in a manner similar to control of the fire pump valves, as previously discussed. Operating features and protection of the circuits should be the same as for the fire pump valves.

The effectiveness of the automatic sprinkler system will be related to the ship stability. The traditional sprinkler discharge pattern may be affected by ship movement, particularly during a heavy sea or icebreaking operations. This effect on the discharge pattern is offset by use of the deluge system throughout the compartment with all sprinklers operating. A change in the pattern from one sprinkler will be compensated for by the other sprinklers which are operating.

Closed sprinklers are not advisable in this situation due to the possibility of ship movement, changing the discharge pattern from an individual sprinkler. A closed-head sprinkler system may be less effective during a heavy sea or during icebreaking operations than an open-head system.

Automatic operation of the sprinkler system, using an open-head deluge system, is not necessary if a detection system is provided within the protected compartment and rapid manual response is effected. Operation of the systems should be by the responding fire fighters, after they have determined that they cannot control the fire with hand hose lines. Remote operation of the system should occur only if fire fighting forces cannot approach the compartment. This is to prevent related damage caused by the deluge sprinkler system water.

The sprinkler density of 0.20 gpm per square foot exceeds the recommended density of 0.19 gpm per square foot for a 1,500 foot design area contained in NFPA Standard 13 for Ordinary Hazard Group 2 uses. This density should be adequate to protect storage within the compartments to a maximum height of 12 feet according to NFPA 13.

Strengths and weakness of the seawater sprinkler systems are summarized as follows:

SEA WATER SPRINKLER SYSTEMS

STRENGTHS

1. Discharge density meets or exceeds NFPA 13 criteria for the hazard protected. Rapid fire control should occur.

2. Open head, deluge-type system will compensate for ship stability and the effect on discharge from each sprinkler by operating all sprinklers within the compartment.

WEAKNESSES

1. Water damage may exceed fire damage. This type of system should be a second line of defense, behind the first line manual fire fighting activity with hand hose lines. An assessment of total damage potential should be made prior to operating this type of system. That total damage potential includes both fire damage and fire suppression agent damage.

7.2.8 AFFF HAND HOSE LINES

SYSTEM DESCRIPTION

The AFFF hand hose lines will be supplied from fire plugs which are similar to the seawater fire plugs. The difference between the AFFF hand hose line and the seawater hand hose line will be the type of nozzle and the fact that the fire plug is supplied from the AFFF fire main with foam solution rather than with seawater from the seawater fire main.

DISCUSSION

The same considerations apply to the AFFF hand hose lines as to the seawater hand hose lines.

Fresh AFFF solution will not be immediately available at the nozzle. It will take time to fill the fire main with fresh solution once the nozzle is opened. This time will be affected by the piping volume between the hose line and foam proportioner.

The AFFF solution mix may be outside of the effective range of the foam proportioner when a single hose line is used. The solution mix should be adequate when two hose lines are used as the flow rate should be above the minimum proportioner flow rate when two lines are in use. This should not be a problem in terms of fire fighting effectiveness, the mix will probably contain more AFFF concentrate, making it a more effective foam solution, but using the foam concentrate at a faster rate than necessary.

Strengths and weaknesses are the same as for seawater hand hose lines with the exception that AFFF solution will be more effective on a flammable liquid fire.

7.2.9 AFFF SPRINKLER SYSTEMS

SYSTEM DESCRIPTION

Current specifications call for an open-head AFFF sprinkler system capable of producing a discharge density at a rate of 0.16 gpm per square foot over the protected area. This discharge rate is a Navy requirement, exceeding the NFPA Standard 11 requirement of 0.10 gpm per square foot by 60 percent. This discharge rate is to be maintained for a 10-minute period.

Because the sprinkler systems will be open-head sprinkler systems, all sprinkler systems within a protected compartment should operate concurrently. If a compartment contains multiple levels of sprinkler systems, such as in an engine room where sprinklers are provided both in the bilge and at the overhead, both sprinkler systems should operate together. If this does not happen, a fire may not be controlled.

DISCUSSION

Proper operation of the AFFF sprinkler system depends upon operation of the foam proportioner. If the foam proportioner does not deliver a proper solution mix to the system, the effectiveness of the system will be reduced.

Operation of the AFFF sprinkler system control valve should be in the same manner as the seawater sprinkler system control valve.

The AFFF foam blanket can be affected by ship movement and the type of nozzle used. If a non-air aspirated sprinkler nozzle is used, the expansion ratio will be in the range of 2/4 to 1. The ability of the foam to flow is better at this expansion ratio than with a higher ratio achieved with an air-aspirated nozzle. However, the holding power (25 percent drainback time) will probably be less.

This compromise, sacrificing the holding power of the foam blanket for improved foam flowability, is probably a good tradeoff in an engine compartment and bilge where there are many obstructions which the foam blanket will need to flow around. The foam system fire control ability should be better than with an air-aspirated nozzle and its 8/10 to 1 expansion ratio, but with less ability of the foam solution to flow around obstructions.

The strengths and weaknesses of the AFFF sprinkler system are summarized as follows:

AFFF SPRINKLER SYSTEM

STRENGTHS

1. Foam solution discharge rate exceeds the criteria of NFPA 11 by 60 percent. Rapid fire control should occur if the ship is reasonably steady.

WEAKNESSES

1. The system may not be effective during unsteady ship conditions, such as in a heavy sea or while icebreaking because of agitation of the fuel/foam blanket. This can cause breakdown of the foam blanket and release of fuel vapors.

2. System operation will cause water/foam solution damage, particularly to energized electrical or electronic equipment. The salt water/foam solution is electrically conductive. The system should be used on large flammable liquid spill fires where manual control using hand hose lines is not possible. The system should be operated by fire fighters on the scene rather than remotely operated from the ECC or DCC.

7.2.10 AFFF MONITOR NOZZLE

SYSTEM DESCRIPTION

None proposed for use in the protected compartments under consideration.

DISCUSSION

An AFFF monitor nozzle is useful in large open spaces where the nozzle stream is required to "reach" a distant fire or to sweep a fuel spill from under an aircraft into a collection and drainage system. It would not be useful in the helicopter hangar or engine room due to the confined spaces, obstructions within the spaces, lack of visual control for the monitor operator from a remote point and ship movement which could defeat the sweeping function of the monitor nozzle.

A monitor nozzle may be useful to protect the helicopter landing area where manual fire fighting may be difficult in the event of a helicopter crash. If a monitor nozzle or nozzles are provided to protect a helicopter landing area, factors which should be considered in nozzle and monitor selection are:

1. Declination and inclination angle limitations of the monitor.

2. Ability to conduct an automatic, programmed sweep in two to three dimensions.

3. Ability to remotely control the monitor nozzle and to see the effect of the nozzle discharge. The control point would need to be at a location where visibility would not be obstructed either by the fire or by smoke from the fire.

4. Blind spots created by the ship structure or helicopter and the need for two or more nozzles to cover the blind spots.

5. The type of monitor operator. A water motor-type operator probably would not be suitable with the monitor nozzles located exposed to the weather. Electric operators would be needed.

6. Protection of the moving monitor nozzle parts from ice accumulations when exposed in freezing weather. A housing may be needed to shield the monitor nozzle operating mechanism and prevent ice buildup with subsequent jamming of the mechanism.

A monitor nozzle supplied by the AFFF systems proposed would not be effective in personnel rescue in the event of a helicopter crash. The reason for this is the time delay needed to:

1. Start the fire pump and pressurize the fire main,

2. Open the foam proportioning equipment valves and start the foam proportioner pump,

3. Fill the AFFF fire main with foam solution,

4. Open the AFFF monitor nozzle valve to allow foam solution through the monitor nozzle.

This time delay will probably be at least a minute, perhaps longer. This will effectively prevent use of the AFFF monitor nozzle as an effective rescue tool in the event of a crash fire.

7.2.11 HALON 1301 TOTAL FLOODING SYSTEM

SYSTEM DESCRIPTION

Current specifications call for a Halon 1301 system capable of producing a 6 percent design concentration within the protected compartment. The system is a total flooding type system. A preconnected reserve is provided, allowing for a second discharge or restoration of the system to service after an initial discharge. This will allow continued protection until the primary system can be recharged. The system is to be actuated by a Navy-type carbon dioxide actuation system with remote actuators at the ECC and DCC.

DISCUSSION

The typical Navy-type Halon actuation system is not supervised. The actuating tubing can loosen, particularly if it is subject to vibration over an extended period of time. If the tubing is disconnected, the CO_2 actuating gas could be lost, preventing actuation of the Halon system from any location. The carbon dioxide within the actuating storage bottles at each actuating station is not monitored. It is possible to lose the carbon dioxide in an actuating cylinder without knowing about it.

The protected compartment needs to be reasonably vapor tight prior to Halon system discharge. This is to prevent loss of agent, lowering the concentration below an effective level. Compartment openings need to be closed and ventilating systems secured prior to system discharge. For this reason, the Navy-type actuating system has a discharge time delay which permits up to a 60-second delay between when the system is activated and when Halon is discharged.

Auxiliary relays can be installed on the actuating system ahead of the time delay to perform functions immediately upon operation of a manual station. Such functions would be securing ventilation fans, closing dampers, closing hatches, shutting down diesel engines, and sounding a predischarge alarm. Relays can also be installed downstream of the time delay, causing a system discharge alarm to sound and allowing operation of functions desired at the time of system discharge.

The actuating system does not have a means for manual system discharge abort as is normally provided on an automatically operated system. The manually activated system is not expected to be operated unless there is an actual need for system discharge.

Auxiliary functions which are to occur either at the time of system operation or at the time of system discharge should have their control circuits monitored by the fire alarm system as Class "A" circuits. This is necessary to ensure that the auxiliary functions will occur. For example, if the ventilation

fans are not secured because the control circuit is defective, the Halon could be dissipated from the compartment, reducing the fire fighting effectiveness of the system.

All auxiliary function control circuits should be supervised and arranged so that a fire in the protected compartment will not endanger those circuits. Supervision should consist of monitoring the electrical integrity of the circuits and the power supply to those circuits. Supervision should occur at both the ECC and DCC. Indication of the status of the auxiliary functions should also be provided at both the ECC and DCC using Class "B" circuits. The fire control team should know if the ventilation system has not been properly secured, if an engine has not been shut down, or if compartment openings have not been closed before they attempt to enter the compartment.

The Halon system should be manually activated by the responding fire fighting crew or by the compartment occupants if the compartment must be continuously occuppied. It should not be operated from a remote location except when the fire fighting crew cannot approach the protected compartment. Operation of the system will result in a significant system recharge cost. Consequently, it should be used only when determined necessary for fire control.

Strengths and weaknesses are summarized as follows:

<u>HALON 1301 TOTAL FLOODING SYSTEM</u>

<u>STRENGTHS</u>

1. Design concentration specified should control fire while allowing personnel to remain in the compartment if there is a critical need to man the compartment.

<u>WEAKNESSES</u>

1. Compartment preparation is critical to maintaining adequate extinguishing concentration. Auxiliary functions which prepare compartment prior to discharge must all occur successfully.

2. Navy-type actuating system cannot be monitored. Reliance must be placed on routine inspection of the system.

3. Recharge cost will be higher than for other types of systems.

4. All auxiliary functions should be equipped with Class A control circuits and have the control circuits supervised.

5. Establish a procedure for determining need to operate this system to ensure that it is not operated when other means of fire fighting could be effective with less total damage (fire damage and system recharge cost).

7.3 ACTIVE FIRE SAFETY EVALUATIONS OF TYPICAL COMPARTMENTS

Eight typical compartments have been considered as a part of this evaluation. These include:

1. Engine Room No. 1 - Compartment No. 5-100-0-E
2. Engineering Control Center - Compartment No. 2-223-0-C
3. Dry Laboratory - Compartment No. 1-239-0-Q
4. Science Storage - Compartment No. 3-311-0-AA
5. Crew Berthing - Compartment No. 2-121-4-L
6. Arctic Gear Locker - Compartment No. 1-307-2-A
7. Ship Office - Compartment No. 1-198-2-Q0
8. Helicopter Hangar - Compartment No. 02-228-0-Q

7.3.1 ENGINE ROOM NO. 1 (5-100-0-E)

Compartment Description - Engine Room No. 1 will be used to house diesel engine/generator sets and various pieces of ship's machinery. It is assumed the compartment will not normally be occupied when in port and will be occupied approximately 15 percent of the time when at sea. The compartment is located on the third, fourth, and fifth decks aft of frame 100 and occupies an area of approximately 2,400 square feet. The compartment extends into the uptakes. Entry is made at the third deck level. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this engine room.

Fire Scenarios - The fire scenarios considered are:

1. An oil spray fire (either lubricating or fuel oil) at a flow rate of less than 1 gallon per minute. The oil spray will stop when the equipment being served by that oil is shut down.

2. An oil spill fire, either lubricating oil or fuel oil, at a flow rate over 1 gallon per minute. The fuel spill will continue after the associated equipment is shut down.

3. A fire in bundled cables located in the compartment overhead.

Fire Detection Systems - Compartment fire detection systems recommended based on Navy work (see section 7.1) include systems using rate-of-rise detectors, flame detectors (either ultraviolet or infrared), and photoelectric-smoke detectors.

A photoelectric-smoke detector will probably create false alarms or will not alarm under a fire condition as it is affected by the engine room environment. It is expected that an oily film and residue buildup will occur on all surfaces within the engine room because of the operating machinery. This will either oversensitize or desensitize the detector, depending upon the type of sensing element within it. The manner in which this detector fails will depend upon its operating principle. In any event, the detector type is not appropriate for this environment.

A flame detector, either ultraviolet or infrared, will probably work if enough detectors are provided to avoid blind spots and the detector lens is supervised to ensure that lens obstruction does not occur due to a residue buildup. This type of detector should respond within a maximum of 1 second to an open flaming fire as would be expected from an oil spray or spill fire.

Feb 02, 1989

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 5-100-0-E ENGINE ROOM NO.1 (TANK TOP LEVEL)
Zero strength barrier above.

USE: E Machinery areas which are normally occupied.

AREA: 2391 sq.ft. DECK HEIGHT: 8.0 ft. VOLUME: 19,135 cu.ft.

UNACCEPTABLE LOSS: Code 3 (Full compartment lost to fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.0330 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0474

FUEL LOAD: 18,916 BTUs/sq.ft.
Cable, paint, etc., (40gpm x 6m/compartment area)

VENTILATION: 19,135 cu ft/min EXCHANGE TIME: 1.0 min.
VENT AREA: 2100 sq.in. VENT HEIGHT: 70 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	0	6	85	10
Tbar Failure	5	6	20	40
Dbar Failure	5	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

Assumes a fuel or lube oil line rupture
No line rupture as adjacent compartment

DETECTION:
Manual:
Occupied 0% of time in port and 15% of time at sea.
Automatic:
Rate of temperature rise detection system (RR)
Photo electric smoke detection system (P)
Flame detection system (UV or IR) (F)

FIRST AID FIRE PROTECTION:
2 Hand portable carbon dioxide fire extinguisher
4 Hand portable dry chemical fire extinguisher (PKP)

AUTOMATED FIRE PROTECTION SYSTEMS:
1 Halon 1301 total flooding system - remotely actuated
1 AFFF (3%) sprinkler system - remotely actuated

MANUAL FIRE FIGHTING EQUIPMENT:
1 1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.
2 1 1/2" AFFF (3%) hand line with SFL variable nozzle 50 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 5-100-0-E ENGINE ROOM NO.1

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
5-100-1-F	OIL TANK	W8	0	491.2	80	100	5
5-100-2-F	OIL TANK	W8	0	491.2	80	100	5
5-162-0-E	ENGINE ROOM NO.2	W8	0	336.0	80	100	5
5-76-0-E	BOW THRUSTER MACHINERY RO	W8	0	288.0	80	100	5
4-100-0-E	ENGINE ROOM NO.1	C0	0	2390.6	0	0	100
			--				
			0				

Such a sophisticated detector is not needed in this compartment because the fire suppression will not be automatic. This type of detector does have value when fast detection and fast automatic fire suppression is to occur. The cost and maintenance required for this detector make it an inappropriate choice for use in this compartment as long as the fire suppression is to be manually activated. This detector type could create false alarms due to normal conditions within the compartment such as electric arcing or heat buildup within a piece of machinery.

A rate-of-rise detector will respond quickly to a flammable liquid fire such as a fuel or lubricating oil spill or spray fire. There exists a possible false alarm problem with this type of detector when a diesel engine or other piece of equipment which produces heat is started from a cold stop.

Spot-type fixed temperature detectors, adequately spaced throughout the compartment, should be sufficient to alert the crew to a flammable liquid fire in a timely manner. A combined use of fixed temperature and rate-of-rise detectors may be useful if the rate-of-rise detectors are on a separate zone so that they could be disabled when equipment is started from a cold stop to reduce the potential for false alarms.

A bundled cable fire will not be easily detected by a rate-of-rise detector, a spot-type fixed temperature detector or flame detectors. If bundled cables are to be present within this compartment, a line-type, fixed temperature detector located directly in the bundled cables may be an appropriate detector type.

Beam type smoke detectors are not considered suitable for this compartment or for use on this ship because of the problem of keeping the beam mirrors in proper alignment. Ship vibration will probably cause mirror misalignment, making this type of detector inappropriate.

The estimated detection times for various detection systems are shown as follows for both a Class B type fire and for a bundled cable fire:

ESTIMATED DETECTION TIMES - ENGINE ROOM NO. 1

	Detection System	Class B Fire	Bundled Cable Fire
1.	Rate-of-rise detection system	5 seconds	5 minutes +
2.	Flame detection system	1 second	5 minutes +
3.	Photoelectric smoke detection system	Not reliable	Not reliable
4.	Fixed temperature detection system	10 seconds	5 minutes +
5.	Line-type fixed temperature detectors in cable bundles	Not detected	15 to 120 seconds
6.	Crew within compartment	0 to 5 seconds	5 minutes +
7.	Crew outside of compartment	*2 to 5 minutes +	5 minutes +

*Crew may observe unusual engine or engineering plant operating conditions, causing them to enter the compartment to investigate.

This compartment should be protected by a spot-type fixed temperature detection system with detectors located throughout the compartment and a line-type fixed temperature detection system located in the cable bundles. Rate-of-rise detectors could be provided as a separate zone using spot-type rate-of-rise detectors if provision is provided to disable that zone when equipment is started from a cold-stop condition.

The compartment should have two zones (three if rate-of-rise detectors are used), one for the area detectors and one for the bundled cable detectors. Detector circuits should be supervised with both supervisory and fire alarms annunciated at the compartment entry, the ECC and the DCC as discussed in Section 7.1.

An alternative zoning method would be to zone the detection systems vertically, so that the detectors at the overhead are on

one zone and detectors located below obstructions are on additional zones. This will probably be of little value in detecting or responding to a Class B type fire.

The photoelectric smoke detector will probably not work in this compartment and should not be installed. The flame detector will work, but is expensive and maintenance intensive. The detector speed provided by this type of detector is not needed as long as the fire suppression activities will be manually initiated. As shown in the table above, the expected operating time difference between a flame detection system and fixed temperature detection system is small when the overall fire response time is considered.

If this compartment is provided with telephone communication capability between the ECC and DCC, so that an alarm can be sounded when the compartment is occupied, a manual fire alarm station is not needed. If this telephone communication link is not provided, a manual alarm station should be provided at each compartment egress point.

Portable Fire Suppression - The compartment is to be protected by two, 1-1/2 inch AFFF hand hose lines with SFL nozzles, four Purple-K type fire extinguishers, and two carbon dioxide portable fire extinguishers.

The AFFF hand hose lines can be effective on a flammable liquid spill or spray fire after the associated equipment is shut down and the oil spray stopped. The remaining fire should be in the residual oil spilled on the deck or sprayed on vertical surfaces.

If the manual fire fighting effort succeeds in putting out an oil spray or spill fire before the equipment causing the spray or spill is shut down and the ignition source which originally started the fire is not eliminated, the fire will re-ignite.

Manual fire fighting with AFFF hand hose lines can be an effective first line of fire defense on oil spray or spill fires when the associated equipment is shut down. Manual fire fighting with a hand hose line will probably not be effective on a large spill fire in this compartment.

The portable fire extinguishers may also be effective on a residual oil fire or small electrical fires. As with the hand hose lines, the associated equipment must be shut down before portable fire extinguishers can be effective.

The hand hose lines should not be used on energized electric cable bundle fires. If the cables are located in the overhead, it is questionable whether carbon dioxide fire extinguishers would be effective on a bundled cable fire.

The cables would need to be de-energized prior to manual fire fighting to avoid a personnel hazard to the fire fighting crew and to eliminate the initial ignition source. If the cables are not de-energized, the crew could be injured or the fire could re-ignite as long as the original ignition source remains.

The ability to control fire manually within this compartment depends upon the operator training and ability along with the sea condition as it affects access into the space and the stability of the fire fighters' working platform. If the ship is steady, a trained fire fighting crew should be able to effectively manually control any fire in this compartment, other than a large flammable liquid spill fire, assuming that the diesel engines have been shut down and the electrical equipment in the compartment is de-energized. If the ship is unsteady, the ability to control fire may be impaired.

If the diesel engines are not shut down and the electrical equipment and cables not de-energized, manual fire fighting efforts will probably not be effective.

Controls should be provided to manually stop both diesel engines in the compartment at the compartment entrance, at the ECC, and at the DCC. Controls should also be provided at those three locations to secure the ventilation system, shut down ventilation fans, close intake and exhaust dampers, and close other openings in the compartment which are normally open.

The control circuits to stop the engines and to secure the compartment ventilation system should be installed in the same manner as other control circuits, as discussed in Section 7.1. Indication of the status of the diesel engines, the ventilation system, and other compartment openings should be provided at the control locations.

Bundled electrical cables should be removed from this compartment or enclosed in tight cable trays which can be flooded with carbon dioxide or Halon 1301 as a means of suppressing fire. Provision should be provided to shut off power to the cable bundles in the event of fire.

<u>Fixed Fire Suppression Systems</u> - This compartment is to be protected by a manually operated Halon 1301 total flooding system and a manually operated AFFF sprinkler system with sprinklers installed at the overhead and in the bilge.

We have assumed that the AFFF sprinkler system protecting the overhead is arranged with sprinklers at the overhead only, without sprinklers under obstructions formed by equipment, decks, or ductwork.

The AFFF overhead and bilge systems need to operate concurrently because of the possibility of a three-dimensional fire. AFFF sprinklers are also needed under obstructions so that a flammable liquid fire is not allowed to burn in an area shielded from the AFFF discharge. The AFFF proportioner size seems small for this combined demand. This should be checked to make certain that the proportioner is adequately sized.

The AFFF will be effective on a large spill fire under a steady ship condition. It may not be effective on a large spill fire under unsteady ship conditions if there is constant agitation of the fuel and foam mixture, destroying the sealing effect of the foam blanket.

The design density of 0.16 gpm per square foot exceeds the NFPA Standard 11 criteria of 0.10 gpm per square foot by 60 percent. This should provide an adequate safety factor, enabling the AFFF sprinkler system to control almost any flammable liquid spill fire situation which may occur in this compartment under steady ship conditions. As with the AFFF hand hose lines, this assumes that the diesel engines will have been shut down prior to the fire fighting operation. If the diesel engines had not shut down so that the source of fuel and ignition is not eliminated, the fire may be controlled for a time, but could eventually re-ignite once the foam blanket has broken down or the foam discharge stopped.

The AFFF sprinkler system is the second line of defense to the primary AFFF hand hose line systems for an oil spill or spray fire. In order for the AFFF sprinkler system to be effective, it needs to be a complete system, with protection provided below obstructions where a spill or spray fire may be shielded from the sprinkler discharge. If the system is not complete, fire could burn in the shielded areas without being controlled.

The Halon 1301 system is the third line of defense for an oil spill or spray fire, being effective under unsteady ship conditions where the AFFF system may have difficulty in securing an oil spill fire. If used as the third line of defense, the Halon discharge should occur concurrently with use of the reserve AFFF supply to provide the maximum fire fighting capability in the compartment.

The Halon 1301 system would be the second line of defense for an electrical generator fire or for a cable bundle fire.

In order for the Halon system to be effective, the compartment ventilation must be secured, all compartment openings closed, and the diesel engines shut down prior to system discharge. This should occur at the first attempt at manual fire fighting. However, controls should be provided, activated by relays on the Halon operating system, to ensure that these auxiliary functions do occur prior to Halon system discharge.

The estimated effectiveness of the various fixed and portable fire suppression systems is shown in Table 7.2. Table 7.2 assumes that the diesel engines are shut down, that the compartment ventilation is secured, that the compartment openings are closed, and that electrical cables and equipment are de-energized prior to fire fighting operations.

TABLE 7.2

ESTIMATED FIRE SUPPRESSION SYSTEM EFFECTIVENESS - ENGINE ROOM NO. 1

System Type	Spill Fire - Ship Steady	Spill Fire - Ship Unsteady	Spray Fire - Ship Steady	Spray File - Ship Unsteady	Bundled Cable Fire
1. Portable Fire Extinguishers	X	X	P	D	D
2. AFFF Hand Hose	D	X	E	P	P*
3. AFFF Sprinkler and Hand Hose - No Sprinklers Below Obstructions	P	D	E	E	P
4. AFFF Sprinkler and Hand Hose - Complete Sprinkler Protection	E	D	E	E	P
5. Halon 1301P	P	E	E		
6. Halon 1301 and AFFF Sprinkler Combined	E	P/E	E	E	P

This evaluation assumes that diesel engines are shut down, ventilation system secured, electrical equipment de-energized prior to fiDe fighting activity.

*Personnel safety hazard if electrical cables are not de-energized.

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions.
X	System is not expected to be effective.

7.3.2 ENGINEERING CONTROL CENTER (2-223-0-C)

Compartment Description - The Engineering Control Center will be used as a control center, as the name implies. It is assumed the compartment will be occupied on a continuous basis. Located on the second deck, the compartment has an area of approximately 1,700 square feet and a height of approximately 9 feet. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenarios - The two fire scenarios considered are:

1. An electronic equipment cabinet fire.

2. A wastebasket-type fire.

Fire Detection Systems - Navy work indicates the compartment should be protected by rate-of-rise heat detectors and photoelectric smoke detectors (see section 7.1).

The primary means of fire detection will be the crew, who will constantly occupy this compartment. The photoelectric smoke detector will be the secondary level of protection, while the rate-of-rise detector will be the third level of protection, providing redundant automatic detection. As recommended for Engine Room No. 1, the detector circuits should be supervised with each type of detector on a different zone.

Detection does not appear to be provided in the electronic equipment cabinetry. We assume that the cabinetry will be vented into the room so that smoke or odor from a fire within a cabinet will be readily apparent and Halon will be able to enter the cabinetry when the compartment system discharges. The cabinetry will probably have openings for normal ventilation and heat dissipation.

Fire alarm signals from the ECC should be remotely indicated at the DCC.

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 2-223-0-C ENGINEERING CONTROL CENTER

USE: C Ship and fire control operating areas normally occupied.

AREA: 1661 sq.ft. DECK HEIGHT: 9.0 ft. VOLUME: 14,957 cu.ft.

UNACCEPTABLE LOSS: Code 2 (Major item involved in fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.0330 per ship year

FREQUENCY OF ESTABLISHED BURNING: .0012

FUEL LOAD: 12,000 BTUs/sq.ft.

VENTILATION: 7,478 cu ft/min EXCHANGE TIME: 2.0 min.
VENT AREA: 250 sq.in. VENT HEIGHT: 90 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	70	12	90	95
Tbar Failure	55	12	0	70
Dbar Failure	20	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

Always occupied.

DETECTION:
Manual:
Occupied 100% of time in port and 100% of time at sea.
Automatic:
Rate of temperature rise detection system (RR)
Photo electric smoke detection system (P)

FIRST AID FIRE PROTECTION:
4 Hand portable Halon fire extinguisher (1301)

AUTOMATED FIRE PROTECTION SYSTEMS:

MANUAL FIRE FIGHTING EQUIPMENT:
2 1 1/2" Seawater hand line with "all purpose nozzle" 100 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 2-223-0-C ENGINEERING CONTROL CENTER

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
2-210-01-Q	COMPUTER/NAV LAB	W8	0	360.0	80	100	5
2-210-2-TS	STAIRCASE	W8	0	72.0	80	100	5
2-223-1-LP	PASSAGE	W8	2	18.0	80	100	5
2-223-1-LP	PASSAGE	W8	0	36.0	80	100	5
2-223-1-LP	PASSAGE	W8	0	273.6	80	100	5
2-223-2-LP	PASSAGE	W8	0	251.1	80	100	5
2-251-2-A	BATTERY ROOM	W8	0	45.0	80	100	5
2-251-2-A	BATTERY ROOM	W8	0	63.0	80	100	5
2-256-2-TS	STAIRCASE	W8	1	36.0	80	100	5
2-262-1-Q	IC/GYRO ROOM	W8	0	40.5	80	100	5
2-262-1-Q	IC/GYRO ROOM	W8	1	40.5	80	100	5
2-262-1-Q	IC/GYRO ROOM	W8	0	139.5	80	100	5
2-262-2-QF	FAN ROOM	W8	0	153.0	80	100	5
3-223-0-E	MOTOR GENERATOR ROOM	F3	0	1661.9	25	300	5
1-223-0-C	AFT REPAIR NO.3 & DAMAGE	C3	0	608.0	10	100	5
1-223-2-LP	PASSAGE	C3	0	120.6	10	100	5
1-223-4-A	LIFE JACKET LOCKER	C3	0	40.0	10	100	5
1-233-2-A	BOAT GEAR LOCKER	C3	0	24.0	10	100	5
1-239-0-Q	DRY LAB	C3	0	488.0	10	100	5
1-239-1-LP	PASSAGE	C3	0	38.4	10	100	5
1-239-2-A	PHOTO LAB	C3	0	47.6	10	100	5
1-245-1-Q	SCIENCE REEFER MACHY. ROO	C3	0	78.4	10	100	5
1-255-0-Q	ELECTRONICS LAB	C3	0	88.2	10	100	5
1-255-1-A	REEFER	C3	0	67.9	10	100	5
			--				
			4				

The estimated time to detect fire using the various detection means is as follows:

ESTIMATED DETECTION TIMES - ECC

Detection System	Cabinet Fire	Wastebasket Fire
1. Crew	0-30 seconds	0-30 seconds
2. Photoelectric Smoke	60-180 seconds	60-180 seconds
3. Rate-of-Rise Heat Detection	120-300 seconds	120-300 seconds

Note: These estimated times assume that the detectors are installed with a spacing in accordance with their Underwriters Laboratories, Inc., listings and manufacturer's instructions.

Portable Fire Suppression - The compartment will be provided with four Halon 1301 portable fire extinguishers.

The Halon 1301 extinguisher is a clean-agent extinguisher capable of controlling either the wastebasket type fire or an electronic cabinet type fire. The crew within the compartment should be able to control a small fire of either type, assuming that power to energized electric equipment can be cut off so as to remove the ignition source so that re-ignition will not occur.

If there is to be more than a minimal amount of ordinary combustible material (such as paper or cardboard boxes) in this room, a 2-1/2 gallon pressurized water or hand pump-type fire extinguisher should also be provided.

The crew also has the option of using a seawater hand hose line in this room although the fire may have progressed to a point that major damage is done to the equipment prior to being able to put a hand hose line into operation. There will be an inherent time delay in turning on the fire pumps and advancing the hose line into the compartment. A seawater hand hose line used in this compartment could cause considerable damage to the electronic equipment, particularly if the equipment has not been de-energized prior to application of the seawater.

Fixed Fire Suppression - This compartment will be protected by a total flooding Halon 1301 fire suppression system. The system will be designed to produce a 6 percent extinguishing concentration and will be provided with a preconnected reserve. The

system should be capable of being operated from within the compartment, at the entry to the compartment, and at the DCC. Either the system should be equipped with a time delay to allow for securing the ventilation system or additional Halon should be discharged into the compartment to allow for fan rundown and loss through the ventilation system as the ventilation is being secured. The system should also be equipped with auxiliary controls to make certain that all compartment openings are closed prior to system discharge.

Because the system is limited to a 6 percent design concentration, the crew could remain in the compartment during system discharge if there was a need to do so. However, once the system does discharge, the compartment openings should remain closed for at least 10 minutes to allow the extinguishing concentration to be maintained so that fire control can be accomplished.

The first line of fire defense within the ECC will be the crew detecting and reacting to a small fire. If the fire develops to the point were a total flooding Halon system must be used for fire control, or a seawater hose line must be used, major damage will have occurred. The ECC will be out of service for some period of time while that damage is repaired.

The effectiveness of the various fire suppression systems is shown in Table 7.3.

TABLE 7.3
ESTIMATED FIRE SUPPRESSION SYSTEM EFFECTIVENESS - ECC

System Type	Cabinet Fire Ship Steady	Cabinet Fire Ship Unsteady	Wastebasket Fire Ship Steady	Wastebasket Fire Ship Unsteady
Portable Fire Extinguishers - Halon 1301 or Pressurized Water	E	P	E	P
Halon 1301 Total Flooding System	E	E	E	E
Sea Water Hand Hose	E	E	E	E

Note: This evaluation assumes that the affected electronic equipment is de-energized and ventilation systems secured.

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions.
X	System is not expected to be effective.

7.3.3 DRY LABORATORY (1-239-0-Q)

This compartment will be used as a scientific laboratory. It will be occupied approximately 35 percent of the time while at sea, but not occupied while in port. The compartment is located on the first deck and has an area of approximately 500 square feet. The compartment height is 13 feet. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenarios - The two fire scenarios considered are:

1. A flammable liquid spill fire with the spill being less than 1 gallon, approximately 6 square feet in area.

2. Wastebasket type fire.

Should a solvent vapor explosion occur in this compartment, it will probably cause a fire of one of these two types. The planned detection and suppression systems will probably not affect or be affected by such an explosion.

Fire Detection - Fire detection will be accomplished by rate-of-rise detectors and photoelectric smoke detectors.

Experimentation within the laboratory may create fumes or vapors which can cause false alarms or desensitize a photoelectric smoke detector, depending upon its principle of operation. If so, the detector can be removed and replaced with a rate-of-rise detector. The compartment size is such that a single detector should provide adequate coverage.

The two detector types should be arranged on two zones, one for each type of detector. They should be supervised at the ECC and DCC, as are other fire detectors.

Oct 29, 1987

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 1-239-0-Q   DRY LAB

USE: QS   Scientific Spaces

AREA: 488 sq.ft. DECK HEIGHT: 13.0 ft. VOLUME: 6,344 cu.ft.

UNACCEPTABLE LOSS: Code 3 (Full compartment lost to fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.1000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0023

FUEL LOAD: 32,000 BTUs/sq.ft.

VENTILATION: 1,586 cu ft/min   EXCHANGE TIME: 4.0 min.
VENT AREA: 200 sq.in.   VENT HEIGHT: 90 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	15	6	0	30
Tbar Failure	0	6	0	40
Dbar Failure	0	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
  Manual:
    Occupied 0% of time in port and 35% of time at sea.
  Automatic:
    Rate of temperature rise detection system (RR)
    Photo electric smoke detection system (P)

FIRST AID FIRE PROTECTION:
  1 Hand portable monoammonium phosphate fire extinguisher
  1 Hand portable Halon fire extinguisher (1301)

AUTOMATED FIRE PROTECTION SYSTEMS:

MANUAL FIRE FIGHTING EQUIPMENT:
  1 1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.

Oct 29, 1987

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 1-239-0-Q DRY LAB

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
1-223-0-C	AFT REPAIR NO.3 & DAMAGE	W6	0	416.0	10	100	5
1-223-2-LP	PASSAGE	W6	1	208.0	10	100	5
1-239-1-LP	PASSAGE	W6	1	83.2	10	100	5
1-245-1-Q	SCIENCE REEFER MACHY. ROO	W2	0	32.5	25	40	30
1-245-1-Q	SCIENCE REEFER MACHY. ROO	W2	0	124.8	25	40	30
1-255-0-Q	ELECTRONICS LAB	W2	0	234.0	25	40	30
1-255-1-A	REEFER	W2	0	149.5	25	40	30
2-223-0-C	ENGINEERING CONTROL CENTE	F3	0	488.0	25	300	5
01-218-5-LP	PASSAGE	C3	0	54.0	10	100	5
01-239-1-LW	WC & SHR	C3	0	27.0	10	100	5
01-239-2-LW	WC & SHR	C3	0	27.0	10	100	5
01-239-3-L	SCIENTIST SR	C3	0	151.0	10	100	5
01-239-4-L	SCIENTIST SR	C3	0	165.0	10	100	5
01-239-6-LP	PASSAGE	C3	0	64.0	10	100	5
			--				
			2				

The estimated times for fire detection are:

ESTIMATED DETECTION TIMES - DRY LAB

Detection System	Spill Fire	Waste Basket Fire
1. Crew within compartment 35% of time at sea	0 to 5 seconds	0 to 30 seconds
2. Crew outside of compartment	5 minutes +	5 minutes +
3. Photoelectric smoke detector	5 to 10 seconds	60 to 180 seconds
4. Rate-of-Rise heat detector	15 to 30 seconds	120 to 130 seconds

Portable Fire Suppression - The compartment will be provided with a multi-purpose dry chemical fire extinguisher and a Halon 1301 fire extinguisher. Either fire extinguisher should be effective on either type of fire being considered. The choice of using the clean agent extinguisher rather than the dry chemical extinguisher will be up to the user. Table 7.4 shows the estimated fire suppression system effectiveness using the portable fire extinguishers or a seawater hand hose line which is available outside of the compartment. No fixed suppression systems are to be installed in this compartment.

TABLE 7.4

ESTIMATED FIRE SUPPRESSION SYSTEM EFFECTIVENESS - DRY LAB

System Type	Spill Fire - Ship Steady	Spill Fire - Ship Unsteady	Waste Basket Fire Ship Steady	Waste Basket Fire Ship Unsteady
1. Halon 1301 Fire Extinguisher	D	X	E	P
2. Multi-purpose Dry Chemical Fire Extinguisher	P	D	E	P
3. Sea Water Hand Hose Line	E	E	E	E

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions.
X	System is not expected to be effective.

7.3.4 SCIENCE STORAGE - AFT CARGO HOLD (3-311-0-AA)

Compartment Description - This will be a storage hold which is not normally occupied. The compartment is located on the third deck and has an area of approximately 2,000 square feet with a 10-foot compartment height. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenario - The fire scenario considered is a cargo fire involving stored cardboard boxes.

Fire Detection - The compartment will be protected by rate-of-rise heat detectors and photoelectric smoke detectors.

As previously discussed, the detectors should be on two separate zones, zoned by type and supervised at the ECC and DCC.

A photoelectric detector is a redundant detector which is probably not needed in this compartment. The following table shows the estimated detection times:

ESTIMATED DETECTION TIMES - SCIENCE STORAGE

	Detection System	Cargo Fire
1.	Crew in compartment	0 to 60 seconds
2.	Crew outside of compartment	5 minutes +
3.	Rate-of-rise detection system	120 to 240 seconds
4.	Photoelectric detection system	60 to 240 seconds

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 3-311-0-AA SCIENCE STORAGE--AFT CARGO HOLD

USE: AA Cargo Holds

AREA: 2058 sq.ft. DECK HEIGHT: 10.0 ft. VOLUME: 20,583 cu.ft.

UNACCEPTABLE LOSS: *Code 3 (Full compartment lost to fire)*
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.1000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0009

FUEL LOAD: 1,600,000 BTUs/sq.ft.
Loaded cardboard boxes--Fuel load in psf = 25 x height of deck.

VENTILATION: 2,058 cu ft/min EXCHANGE TIME: 10.0 min.
VENT AREA: 100 sq.in. VENT HEIGHT: 20 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	30	12	70	40
Tbar Failure	20	12	50	60
Dbar Failure	10	*	10	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
Manual:
Occupied 5% of time in port and 10% of time at sea.
Automatic:
Rate of temperature rise detection system (RR)
Photo electric smoke detection system (P)

FIRST AID FIRE PROTECTION:
1 Hand portable monoammonium phosphate fire extinguisher
1 Hand portable carbon dioxide fire extinguisher

AUTOMATED FIRE PROTECTION SYSTEMS:
1 Seawater sprinkler system - remotely activated

MANUAL FIRE FIGHTING EQUIPMENT:
2 1 1/2" Seawater hand line with "all purpose nozzle" 100 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 3-311-0-AA SCIENCE STORAGE--AFT CARGO HOLD

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
3-271-0-E	AUXILIARY MACHINERY ROOM	W6	0	300.0	10	100	5
3-271-0-E	AUXILIARY MACHINERY ROOM	W6	0	380.0	10	100	5
3-311-2-T	ELEVATOR TRUNK	W6	0	80.0	10	100	5
3-311-2-T	ELEVATOR TRUNK	W6	2	84.0	10	100	5
3-311-2-T	ELEVATOR TRUNK	W6	0	84.0	10	100	5
3-331-1-Q	VENT TRUNK	W6	0	120.0	10	100	5
3-331-1-Q	VENT TRUNK	W6	0	120.0	10	100	5
3-331-1-Q	VENT TRUNK	W6	0	160.0	10	100	5
4-311-0-W	BILGE TANK	F3	0	1242.0	25	300	5
2-311-0-Q	WINCH ROOM	C3	1	2055.2	10	100	5
			--				
			3				

Portable Fire Suppression - The compartment will be protected by a multi-purpose dry chemical fire extinguisher, a carbon dioxide fire extinguisher, and a seawater hand hose line. The portable fire extinguishers may be useful in some fire situations, but probably would not be of significant benefit in controlling a cargo storage fire. The seawater hand hose line will be needed for overhaul and final extinguishment when a fire is controlled by the sprinkler system. A fire in the cargo will probably not be easily controlled by a single hand hose line. The seawater sprinkler system will be needed for fire control.

Fixed Fire Suppression - The compartment is to be protected by a seawater deluge sprinkler system designed to produce 0.20 gpm per square foot over the compartment area. This system design is adequate for an ordinary hazard Group II occupancy which contemplates storage to a maximum height of 12 feet, according to NFPA 13 criteria. Because the compartment height is only 10 feet, this design criteria should be adequate to effect fire control within cargo storage.

The cargo must be kept at least 18 inches below the sprinklers to allow water distribution from the sprinklers. Cargo cannot be stacked tight to the overhead.

The estimated fire suppression system effectiveness is shown in Table 7.5.

TABLE 7.5
ESTIMATED FIRE SUPPRESSION EFFECTIVENESS - SCIENCE STORAGE

System Type	Storage with 18" Clear to Sprinklers, Ship Steady	Storage with 18" Clear to Sprinklers, Ship Unsteady	Storage Tight To Overhead, Ship Steady	Storage Tight To Overhead, Ship Unsteady
Sea water hand hose line	P/D	D	P/D	D
Sea water sprinkler system	P	P	P/D	P/D
Sea water sprinkler system and sea water hand hose line	E	E	P	P

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions.
X	System is not expected to be effective.

7.3.5 CREW BERTHING (2-121-4-L)

Compartment Description - This compartment will be used for crew sleeping quarters. It will be occupied approximately 30 percent of the time at sea and 5 percent of the time while in port. The compartment is located on the second deck, has an area of approximately 300 square feet and a 9-foot height. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenario - A Class A Type fire such as a waste basket or locker fire will be considered.

Fire Detection - It is recommended by Navy work (see Section 7.1) that this type of compartment be protected by ionization-type smoke detectors and photoelectric-type smoke detectors. It is assumed that these will be detectors listed to Underwriters Laboratories, Inc., Standard 268 (UL 268), system-type detectors, rather than single station - UL 217-type detectors. The detectors should be monitored at the ECC and DCC.

Use of two different types of detectors is not necessary in this compartment. Either type of detector should react in approximately the same time in a compartment as small as this. The false alarm potential for the ionization detector will probably be somewhat greater than that of the photoelectric detector. The ionization detector may have false alarm problems because of humidity within the compartment created by the adjoining bath facilities.

The compartment should be provided with a local alarm horn operated off of a set of auxiliary contacts or as an output from the fire alarm control panel (if multiplex system is used) so that when the detector operates, the compartment occupants are alerted, in addition to the alarm sounding at the ECC and DCC.

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 2-121-4-L CREW BERTHING

USE: L10 Berthing Space for 10

AREA: 358 sq.ft. DECK HEIGHT: 9.0 ft. VOLUME: 3,223 cu.ft.

UNACCEPTABLE LOSS: Code 7 (5 compartments of one type lost to fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.1000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0008

FUEL LOAD: 35,730 BTUs/sq.ft.
No. of people x 160/compartment area

VENTILATION: 537 cu ft/min EXCHANGE TIME: 6.0 min.
VENT AREA: 250 sq.in. VENT HEIGHT: 90 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	10	4	0	30
Tbar Failure	5	4	0	50
Dbar Failure	0	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
Manual:
Occupied 5% of time in port and 20% of time at sea.
Automatic:
Ionization smoke detection system (I)
Photo electric smoke detection system (P)

FIRST AID FIRE PROTECTION:
1 Hand portable monoammonium phosphate fire extinguisher

AUTOMATED FIRE PROTECTION SYSTEMS:

MANUAL FIRE FIGHTING EQUIPMENT:
2 1 1/2" Seawater hand line with "all purpose nozzle" 100 ft.

Oct 29, 1987

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 2-121-4-L CREW BERTHING

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
2-100-0-LP	PASSAGE	W6	1	173.7	10	100	5
2-100-0-LP	PASSAGE	W6	0	216.0	10	100	5
2-100-2-L	CREW BERTHING	W6	0	121.5	10	100	5
2-121-2-LW	WR WC & SHR	W3	0	90.0	25	60	25
2-121-2-LW	WR WC & SHR	W3	1	94.5	25	60	25
2-121-3-L	CREW BERTHING	W2	0	83.7	25	40	30
3-100-0-E	ENGINE ROOM NO.1	F3	0	358.2	25	300	5
1-100-2-LP	PASSAGE	C3	0	38.6	10	100	5
1-105-0-Q	GALLEY	C4	0	319.6	25	120	3
			2				

The detection time estimates are:

ESTIMATED DETECTION TIMES - CREW BERTHING

	Detection System	Class A Fire
1.	Crew in compartment, awake	0 - 60 seconds
2.	Crew outside of compartment	5 minutes +
3.	Photo-electric type detector	60 - 120 seconds
4.	Ionization type detector	60 - 120 seconds

Portable Fire Suppression - The compartment will be provided with a multi-purpose dry chemical fire extinguisher. Seawater hand hose lines are available outside of the compartment for use as backup. The estimated fire suppression system effectiveness is shown in Table 7.6.

TABLE 7.6
ESTIMATED FIRE SUPPRESSION SYSTEM EFFECTIVENESS
CREW BERTHING

	System Type	Class A fire Ship Steady	Class A fire Ship Unsteady
1.	Multi-purpose dry chemical fire extinguisher	E	P
2.	Sea water hand hose line	E	E

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions.
X	System is not expected to be effective.

7.3.6 ARCTIC GEAR LOCKER (1-307-2-A)

Compartment Description - This compartment will be used for cold weather gear storage. It will be occupied approximately 10 percent of the time while at sea and 5 percent of the time while in port. The compartment is located on the first deck, has an area of approximately 200 square feet and is 13 feet high. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenario - The fire scenario considered is a Class A fire in the stored cold weather gear.

Fire Detection - It is recommended by Navy work (see Section 7.1) that this type of compartment be protected by a rate-of-rise detector and a photoelectric smoke detector. A single detector should be adequate for this compartment. The photoelectric smoke detector is a redundant detector. If both detectors are used, they should be on separate zones. The estimated detection times are:

ESTIMATED DETECTION TIMES
ARCTIC GEAR LOCKER, SHIP OFFICE

Detection System	Class A Fire
1. Crew in compartment	0 - 30 seconds
2. Crew outside of compartment	5 minutes +
3. Photo-electric smoke detector	60 - 180 seconds
4. Rate-of-rise heat detector	120 - 300 seconds

Portable Fire Suppression - There is no portable fire suppression equipment planned for this compartment. Seawater hand hose lines are available which should be effective in controlling fire both under steady and unsteady ship conditions.

No fixed fire suppression systems are planned for this compartment.

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 1-307-2-A   ARCTIC GEAR LOCKER--SCIENTIST

USE: AG   Small Storage Spaces -- Gear Lockers

AREA: 220 sq.ft. DECK HEIGHT: 13.0 ft. VOLUME: 2,862 cu.ft.

UNACCEPTABLE LOSS: Code 3 (Full compartment lost to fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 1.0000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0009

FUEL LOAD: 120,000 BTUs/sq ft.
Based on hanging wetsuits or parkas

VENTILATION: 286 cu ft/min   EXCHANGE TIME: 10.0 min.
VENT AREA: 10 sq.in.   VENT HEIGHT: 1 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	5	3	0	40
Tbar Failure	5	3	0	30
Dbar Failure	0	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
Manual:
Occupied 5% of time in port and 10% of time at sea.
Automatic:
Rate of temperature rise detection system (RR)
Photo electric smoke detection system (P)

AUTOMATED FIRE PROTECTION SYSTEMS:

MANUAL FIRE FIGHTING EQUIPMENT:
1 1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 1-307-2-A ARCTIC GEAR LOCKER--SCIENTIST

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
1-223-2-LP	PASSAGE	W6	1	150.8	10	100	5
1-271-2-Q	RECOMPRESSION AREA & DIVE	W6	0	104.0	10	100	5
1-302-2-LW	WTR WC & SHR	W3	0	91.0	25	60	25
1-319-0-LP	PASSAGE	W2	0	102.7	25	40	30
1-319-0-LP	PASSAGE	W2	0	104.0	25	40	30
2-295-2-L	CREW BERTHING	F3	0	53.7	25	300	5
2-311-0-Q	WINCH ROOM	F3	0	166.5	25	300	5
01-292-2-LP	PASSAGE	C3	0	58.0	10	100	5
01-311-4-LW	WR WC & SHR	C3	0	38.0	10	100	5
01-311-6-L	SCIENTIST SR	C3	0	73.0	10	100	5
01-319-0-C	SCIENCE & WINCH CONTROL S	C3	0	46.6	10	100	5
			--				
			1				

7.3.7 SHIP OFFICE (1-198-2-QO)

Compartment Description - This compartment will be used as an office and manned approximately 35 percent of the time while at sea and 5 percent of the time while in port. The compartment is located on the first deck, has an area of approximately 225 square feet and is 13 feet high. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follows for further fire safety characteristics of this compartment.

Fire Scenario - A Class A wastebasket type fire is considered.

Fire Detection - The compartment will be protected by a single photoelectric smoke detector. This detector should be adequate to protect the compartment. A rate-of-rise detector would probably protect the compartment just as well, but would have less risk of false alarm problems. The estimated time to detect a fire is shown in the table for the Arctic Gear Locker.

Portable Fire Suppression - The compartment will be protected by a multi-purpose dry chemical fire extinguisher. Seawater hand hose lines will be available outside of the compartment. The multi-purpose dry chemical fire extinguisher should be effective in controlling fire under steady ship conditions and will probably be effective under unsteady ship conditions if the fire is addressed rapidly. The seawater hand hose line should be effective in controlling fire both under steady and unsteady ship conditions.

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 1-198-2-QO SHIP OFFICE

USE: QO Offices

AREA: 225 sq.ft. DECK HEIGHT: 13.0 ft. VOLUME: 2,931 cu.ft.

UNACCEPTABLE LOSS: Code 8 (All compartments of one type lost to fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 1.0000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0004

FUEL LOAD: 20,000 BTUs/sq.ft.

VENTILATION: 488 cu ft/min EXCHANGE TIME: 6.0 min.
VENT AREA: 175 sq.in. VENT HEIGHT: 90 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin	20	5	0	60
Tbar Failure	15	5	0	40
Dbar Failure	5	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
Manual:
Occupied 5% of time in port and 35% of time at sea.
Automatic:
Photo electric smoke detection system (P)

FIRST AID FIRE PROTECTION:
1 Hand portable monoammonium phosphate fire extinguisher

AUTOMATED FIRE PROTECTION SYSTEMS:

MANUAL FIRE FIGHTING EQUIPMENT:
1 1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 1-198-2-QO SHIP OFFICE

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
1-162-2-LP	PASSAGE	W6	1	111.8	10	100	5
1-178-4-QO	SUPPLY OFFICE	W2	0	104.0	25	40	30
1-187-2-QO	1ST LT OFFICE	W2	0	136.5	25	40	30
1-206-2-QO	EXO OFFICE	W2	0	136.5	25	40	30
1-206-2-QO	EXO OFFICE	W2	1	156.0	25	40	30
1-207-2-LP	PASSAGE	W2	0	135.2	25	40	30
2-195-2-Q	FIREFIGHTING EQPT ROOM	F3	0	221.2	25	300	5
01-178-2-W	ROLL STABILIZATION TANK	C3	0	114.0	10	100	5
			--				
			2				

7.3.8 HELICOPTER HANGAR (02-228-0-Q)

Compartment Description - This compartment is used as a helicopter storage hangar and cargo staging area. It will be occupied approximately 25 percent of the time at sea and 5 percent of the time while in port. It is located on the 02 Deck, has an area of approximately 2,100 square feet and a height of approximately 18 feet. See the Compartment Fire Safety Summary and Barrier Fire Safety Summary which follow for further fire safety characteristics of this compartment.

Fire Scenarios - The two fire scenarios considered are:

1. Fuel spill fire.

2. Class A fire while the compartment is used for cargo staging.

Fire Detection System - Based on Navy work (see Section 7.1) the compartment would be protected by flame detectors (either ultraviolet or infrared) and photoelectric smoke detectors. A flame detector may cause false alarms when the hangar door is open due to shimmering sunlight reflecting from the sea.

A photoelectric smoke detector may cause false alarm problems when an engine is running in the compartment, either a helicopter engine or a tractor engine. The compartment is located astern of the main engine exhaust stacks. Exhaust gases from the main diesel engines may enter the compartment under unfavorable wind conditions, causing the photoelectric smoke detectors to false alarm.

Both detectors may false alarm or not operate when the hangar door is opened if a temperature differential exists between the hangar and the exterior. This condition could be aggravated by humidity within the hangar.

Rate-of-rise detectors may false alarm when the hangar door is opened and closed in cold weather. Helicopter engine heat could also trip a rate-of-rise detector.

A fixed temperature detection system is needed.

Feb 02, 1989

COMPARTMENT FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/1987)

Compartment: 02-228-0-Q HANGAR (02 LEVEL)
Zero strength barrier below.

USE: Q Areas usually unoccupied: engineering, electronics, galleys

AREA: 2108 sq.ft. DECK HEIGHT: 9.0 ft. VOLUME: 18,972 cu.ft.

UNACCEPTABLE LOSS: Code 2 (Major item involved in fire)
THRESHOLD FREQUENCY OF UNACCEPTABLE LOSS: 0.1000 per ship year

FREQUENCY OF ESTABLISHED BURNING: 0.0038

FUEL LOAD: 0 BTUs/sq.ft.

VENTILATION: 3,162 cu ft/min EXCHANGE TIME: 6.0 min.
VENT AREA: sq.in. VENT HEIGHT: 0 in.

FIRE STARTED DUE TO:	I	FRI Time	A	M
Fire Origin			0	0
Tbar Failure	0		0	0
Dbar Failure	0	*	0	0

* calculated as (100 - % Heat Release)/100 X FRI Time or 2 min., whichever is greater.

DETECTION:
Manual:
Occupied 5% of time in port and 25% of time at sea.
Automatic:
Photo electric smoke detection system (P)
Flame detection system (UV or IR) (F)

FIRST AID FIRE PROTECTION:
2 Hand portable carbon dioxide fire extinguisher
5 Hand portable dry chemical fire extinguisher (PKP)
2 Hand portable Halon 1211 fire extinguisher

AUTOMATED FIRE PROTECTION SYSTEMS:
1 AFFF (3%) sprinkler system - remotely actuated

MANUAL FIRE FIGHTING EQUIPMENT:
1 1 1/2" Seawater hand line with "all purpose nozzle" 50 ft.
1 1 1/2" AFFF (3%) hand line with SFL variable nozzle 100 ft.

BARRIER FIRE SAFETY SUMMARY
FOR
POLAR ICEBREAKER REPLACEMENT
(drawings dated 5/12/87)

Compartment: 02-228-0-Q HANGAR

Barriers (Adjoining Compts ID and Name)		Mat ID	D/H	Area-sq.ft.	Tbar	Dbar	%heat rel
02-218-0-QO	HELO EQUIP ROOM & OFFICE	W2	1	342.0	25	40	30
01-218-5-LP	PASSAGE	F3	0	84.7	25	300	5
01-218-6-LP	PASSAGE	F3	0	98.1	25	300	5
01-218-8-A	SCIENCE BAGGAGE ROOM	F3	0	45.2	25	300	5
01-222-1-L	SCIENTIST SR	F3	0	130.0	25	300	5
01-222-2-L	SCIENTIST SR	F3	0	77.1	25	300	5
01-225-0-L	SCIENTIST SR	F3	0	101.6	25	300	5
01-239-1-LW	WC & SHR	F3	0	27.0	25	300	5
01-239-2-LW	WC & SHR	F3	0	27.0	25	300	5
01-239-3-L	SCIENTIST SR	F3	0	165.0	25	300	5
01-239-4-L	SCIENTIST SR	F3	0	165.0	25	300	5
01-239-6-LP	PASSAGE	F3	0	128.0	25	300	5
01-239-8-A	FAN ROOM	F3	0	64.0	25	300	5
01-255-0-L	SCIENTIST SR	F3	0	137.5	25	300	5
01-255-1-LW	WC & SHR	F3	0	22.5	25	300	5
01-255-2-L	SCIENTIST SR	F3	0	150.8	25	300	5
01-255-3-L	SCIENTIST SR	F3	0	149.3	25	300	5
01-255-4-LW	WC & SHR	F3	0	25.2	25	300	5
01-255-5-LW	WC & SHR	F3	0	26.7	25	300	5
01-255-6-LP	PASSAGE	F3	0	101.6	25	300	5
01-255-8-A	XFMR FECT HELO	F3	0	25.6	25	300	5
01-261-2-TS	STAIRCASE	F3	0	38.4	25	300	5
01-271-1-L	SCIENTIST SR	F3	0	100.0	25	300	5
01-271-2-Q	SCIENTIST LIBRARY/CONFERE	F3	0	150.4	25	300	5
01-271-4-L	SCIENTIST SR	F3	0	37.6	25	300	5
01-277-1-LW	WC & SHR	F3	0	8.8	25	300	5
01-277-3-LW	WC & SHR	F3	0	8.7	25	300	5
01-277-5-L	SCIENTIST SR	F3	0	12.3	25	300	5
03-228-0-Q	HANGAR	C0	0	2088.0	0	0	100
			--				
			1				

The estimated detection times are:

ESTIMATED DETECTION TIMES - HANGAR

Detection System	Spill Fire	Class A Fire
1. Flame detection system	1 second	15-120 seconds
2. Photoelectric smoke detection system	5 seconds	60-120 seconds
3. Rate-of-rise detection system	5 seconds	120-240 seconds
4. Fixed temperature detection system	10 seconds	180-300 seconds
5. Crew in compartment	0-10 seconds	0-30 seconds
6. Crew outside of compartment	5 minutes +	5 minutes +

Because the fire suppression activity within the hangar will be manually activated, the speed given by a flame detector or a photoelectric smoke detector is not needed and will not make a critical difference in the ability to control fire.

A single zone fixed temperature detection system should be provided. A rate-of-rise detection system could be provided on a second zone as a redundant system as long as provision is made to disarm the rate-of-rise detectors to prevent false alarms when engines are running in the compartment or hot engines are brought into the compartment.

Portable Fire Suppression - The compartment will be provided with four AFFF hand hose lines, one dry chemical hand hose line, and multiple portable fire extinguishers. Either the AFFF or dry chemical hand hose lines should be effective on a spill fire during steady ship conditions. The AFFF hand hose lines should be effective on a stored cargo fire during steady ship conditions. The portable fire extinguishers may be effective on small fires but will probably not be effective on a large spill fire.

Fixed Fire Suppression - The compartment will be protected by an AFFF sprinkler system designed for manual operation. The system will produce a density of 0.16 gpm per square foot over the hangar area. Assuming that the sprinkler discharge is complete and not obstructed, the sprinkler system should be capable of controlling any fire occurring within this compartment as long as the stored cargo in the compartment does not exceed 8 feet in height.

The compartment should be provided with a drain system so that the sprinkler discharge water and a fuel spill can be washed overboard or into a holding tank rather than draining into the ship interior on lower levels.

The estimated effectiveness of the fire suppression systems is presented in Table 7.7.

TABLE 7.7
ESTIMATED FIRE SUPPRESSION SYSTEM EFFECTIVENESS - HANGAR

System Type	Fuel Spill Fire Steady Ship	Fuel Spill Fire Unsteady Ship	Cargo Fire Steady Ship	Cargo Fire Unsteady Ship
1. Portable fire extinguisher	P/D	D	D	X
2. Dry chemical hand hose line	P	D	D	D
3. Dry chemical hand hose line and AFFF hand hose line	E	P	P	P/D
4. AFFF sprinkler system	E	P	E	E
5. AFFF sprinkler system and AFFF hand hose line	E	E	E	E

Explanatory Key:

Symbol	Meaning
E	System is expected to be effective in fire fighting.
P	System will probably be effective, but may not be effective under adverse conditions.
D	System effectiveness is doubtful, but the system may be effective under favorable conditions. X System is not expected to be effective.

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8.0 FIRE SAFETY ANALYSIS

The fire safety analysis for the PIR involved a flame movement analysis and a smoke movement analysis. These are presented below. The detailed results of the flame movement analysis are presented in Appendix L. The detailed description of the smoke movement analysis and its results are presented in Appendix M.

8.1 FLAME MOVEMENT ANALYSIS

Many compartments were not considered in the flame movement analysis either because they would not be expected to be involved in a fire or because the SFSEM does not currently handle them properly. A list of these compartments follows:

Refrigerated Storage Spaces (AR - 5 compartments)
Fuel Oil Tanks (F - 35 compartments)
JP-5 Tanks (J - 7 compartments)
Uptakes (TU - 12 compartments)
Voids (V - 6 compartments)
Water Tanks (W - 9 compartments)

COMPARISON OF FLAME MOVEMENT ANALYSIS RESULTS WITH FIRE SAFETY OBJECTIVES FOR PIR

The SFSEM calculations yield the likelihood that the fire will be limited before involving each compartment of the ship given that a fire was established in a specific compartment. This probability of limiting the fire, L, in a target compartment, k, for fire propagating along a fire path, j, due to a fire established in compartment, i, is $Pk(L_j|EB_i)$. (Note; a | stands for given, thus this reads L_j given EB_i). The likelihood, therefore, of not limiting the fire and, hence, losing the compartment is:

$$P_k(Lbar_j|EB_i) = 1 - P_k(L_j|EB_i)$$

In order to evaluate the performance of the ship relative to the Fire Safety Objectives, it is necessary to express the SFSEM results in terms of the frequency of expected loss of each compartment. In order to establish these frequencies it is necessary to evaluate the effect on a compartment, k, of fires initiated in all possible compartments of fire origin. The compartment, k, is called the target.

The fire simulation is run for a room of origin, i. Each target compartment, k, is examined to establish which fire paths, j, connect the room of origin and the target room. The level of loss in the target room being considered is given by the mission critical loss definition for the target space. Thus, the notation, L, indicating limiting the fire may refer to EB in spaces where the loss code is 1, single item involvement where the loss code is 2, or FRI where the loss code is 3 or greater, depending on the fire safety objectives for the target space. This will be implicit in what follows.

The likelihood of target room loss due to fire initiated in room, i, is found by summing over all available fire paths, j:

$$P_k(Lbar|EB_i) = sum_j\ P_k(Lbar_j|EB_i) \quad (1)$$

The frequency of loss of the target is found by multiplying this by the frequency of EB for each compartment of origin:

$$f_k(Lbar|EB_i) = P_k(Lbar|EB_i)\ f(EB_i) \quad (2)$$

where f(EBi) is the frequency of established burning in the room of origin, i. The total frequency of target loss is found by summing over all compartments of origin:

$$f_k(Lbar) = sum_i\ f_k(Lbar|EB_i) \quad (3)$$

This frequency can be directly compared to the threshold loss frequency objective. In the output from the simulations, it is referred to as the Relative Frequency of Failure|FFS. For convenience the output also lists the fraction that this value is of the Unacceptable Loss Frequency:

$$\text{Fraction of Unacceptable Loss Frequency} = \frac{\text{Relative Frequency of Failure|FFS}}{\text{Unacceptable Loss Frequency}}$$

If $f_k(Lbar)$ is less than the desired threshold loss frequency (i.e., the fraction is less than 1.0), the current design is acceptable with regard to target compartment, k's objectives. Otherwise (i.e., the fraction is greater than 1.0), design changes are required to meet the objectives.

For spaces where a set of multiple compartment losses is required for mission loss (loss code 4 or more), we should consider the likelihood that the set will be lost. Inasmuch as the SFSEM does not calculate deterministic fire scenarios, it is not in general possible to determine the likelihood of simultaneous compartment losses without assuming the compartment losses to be independent events. Therefore, loss codes 4 through 8 are treated in the same manner as loss code 3.

The SFSEM can be run a number of different ways. Options include the state of the ship and its contents and the output representation desired. The options used will be discussed in the context of the results of the analysis. The length of the simulation must also be specified. In principle, one might wish to run the simulation until all fire is extinguished. However, this is both costly and unnecessary. In addition to the objectives already discussed, it will generally be unacceptable to allow fires to continue to burn indefinitely, regardless of the lack of direct effect on mission capabilities. Based on finite resources of the ship and the disruption of ship operations, we can reasonably limit the acceptable fire duration to 40 minutes.

8.1.1 PASSIVE FIRE PROTECTION

Flame movement analysis for passive fire protection simulates the probability that a flame will move through spaces and barriers hampered only by distribution of fuel and the resistance of barriers. Thus it integrates the I, Tbar and Dbar characteristics discussed in Section 3.1 with the pre-flashover and post-flashover fires discussed in Sections 5.4 and 5.5. The results of this analysis are presented in Appendix L1.

The Fraction of Unacceptable Loss Frequency for passive fire protection on the PIR ranges from 0.0000 (for compartments which were not considered in the analysis) to 1.4364. The majority of the compartments met the fire safety objectives and in fact most of them were one to two orders of magnitude better than desired. All compartments where the value of Fraction of Unacceptable Loss Frequency was greater than 0.1000 are listed in Table 8.1.

TABLE 8.1: FLAME MOVEMENT RESULTS
FOR PASSIVE FIRE PROTECTION

-------- Compartment	---------	Fraction of Unacceptable
Number	Name	Loss Frequency
3-100-0	Engine Room No. 1	1.4364
4-100-0	Engine Room No. 1	1.4364
5-100-0	Engine Room No. 1	1.4364
3-162-0	Engine Room No. 2	1.4364
4-162-0	Engine Room No. 2	1.4364
5-162-0	Engine Room No. 2	1.4364
1-178-1	Boiler Room No. 1	1.3697
2-178-1	Boiler Room No. 1	1.3697
1-178-2	Boiler Room No. 2	1.3697
2-178-2	Boiler Room No. 2	1.3697
02-178-0	Emergency Generator Room	0.6182
03-178-2	Auxiliary Generator Room	0.4327
2-361-1	Steering Gear Room	0.2079
2-361-2	Steering Gear Room	0.2079

The only compartments where passive fire protection alone did not meet the fire safety objectives were the Engine Rooms and the Boiler Rooms. The four other compartments are listed because they are less than an order of magnitude improvement over the objectives.

EFFECTS OF OPENING ACCOMMODATION SPACE DOORS

A simulation was run with the accommodation space doors (all doors in compartments with Use Indicators L, L1, L2, L4, L6, L8, L10, LL, LW, Q, QF, QO and QS) open. The complete results are

presented in Appendix L2. In general the doors being open made a substantial difference (see Table 8.2 for examples) for many compartments on the upper decks where most accommodation spaces are located. However, this difference was insignificant in that the Relative Frequencies of Failure of the compartments were still significantly better than the objectives.

TABLE 8.2: EFFECTS OF OPENING ACCOMMODATION DOORS

-------- Compartment ---------		Fraction of Unacceptable Loss Frequency	
Number	Name	Doors Closed	Doors Open
01-100-0	Wardroom and Lounge	0.0048	0.0754
01-118-3	Officer SR	0.0064	0.0247
01-225-0	Scientist SR	0.0064	0.0530
02-120-6	Visitor SR	0.0064	0.0460
02-136-4	Officer SR	0.0064	0.0718

There was no effect on the main deck or below. The remainder of the simulations were run with these doors open. This represents a more severe case. In a real situation all of these doors would not be expected to be open but many of them would be.

EFFECT OF SIMULATION TIME

A simulation was run for 60 minutes to determine the differences between 40-minute and 60-minute runs. The complete results are presented in Appendix L3. Examples of the results are presented in Table 8.3.

TABLE 8.3: EFFECTS OF SIMULATION TIME

-------- Compartment ---------		Fraction of Unacceptable Loss Frequency Simulation Time	
Number	Name	40 min	60 min
01-100-0	Wardroom and Lounge	0.0754	0.0754
01-118-3	Officer SR	0.0247	0.0247
01-162-2	Passageway	0.0014	0.0014
01-225-0	Scientist SR	0.0530	0.0612
02-120-6	Visitor SR	0.0460	0.0460
03-105-0	Radio Room	0.0145	0.0257
03-111-2	Passageway	0.0011	0.0119
1-124-2	CPO Messroom and Lounge	0.0604	0.1095
1-178-6	Supply Officer Office	0.0045	0.0045

There were no appreciable changes below the main deck. The simulation time made a difference for many compartments, very small in some cases and substantial in others. However, even the

substantial differences were insignificant in that the Relative Frequencies of Failure of the compartments were still significantly better than the objectives. This served to verify the choice of the 40-minute simulation time used to run all other simulations.

8.1.2 ACTIVE FIRE PROTECTION

Flame movement analysis for active fire protection integrates the effects of automated systems and manual fire fighting with the passive fire protection discussed above. It provides the second and third lines of defense against unwanted fires. The results of these analyses are presented in Appendices L4 and L5. From Table 8.1 it became apparent that there were only fourteen compartments which required the addition of active fire protection to meet the fire safety objectives. These are listed in Table 8.4 with the effects of including automated and manual fire protection.

TABLE 8.4: FLAME MOVEMENT RESULTS FOR PASSIVE, AUTOMATED AND MANUAL FIRE PROTECTION

Compartment Number	Compartment Name	Fraction of Unacceptable Loss Frequency: Passive	Passive & Auto.	Passive Auto. & Manual
3-100-0	Engine Room No. 1	1.4364	0.2155	0.1939
4-100-0	Engine Room No. 1	1.4364	0.2155	0.1939
5-100-0	Engine Room No. 1	1.4364	0.2155	0.1939
3-162-0	Engine Room No. 2	1.4364	0.2155	0.1939
4-162-0	Engine Room No. 2	1.4364	0.2155	0.1939
5-162-0	Engine Room No. 2	1.4364	0.2155	0.1939
1-178-1	Boiler Room No. 1	1.3697	0.2739	0.2465
2-178-1	Boiler Room No. 1	1.3697	0.2739	0.2465
1-178-2	Boiler Room No. 2	1.3697	0.2739	0.2465
2-178-2	Boiler Room No. 2	1.3697	0.2739	0.2465
02-178-0	Emergency Generator Room	0.6182	0.0927	0.0835
03-178-2	Auxiliary Generator Room	0.4327	0.0649	0.0584
2-361-1	Steering Gear Room	0.2079	0.1894	0.1881
2-361-2	Steering Gear Room	0.2079	0.1894	0.1881

This demonstrates that the inclusion of active fire protection in these compartments has made them substantially safer than the objectives set for them.

8.2 SMOKE MOVEMENT ANALYSIS

The smoke movement analysis was conducted using a modified version of the Building Research Institute (BRI) Fire Model (computer model) to determine the extent of smoke movement from several simulated shipboard fires. The complete analysis is presented in Appendix M. Efforts concentrated on two separate ventilation systems by simulating established burning and determining the extent of smoke movement from these fires. The paint locker was selected as a heavy fuel load compartment and a berthing area was selected as an area with a probability of high loss of life during a fire. Simulations were run for fires in these locations and the data was compared with studies conducted aboard CGC VIGOROUS using SF_6 as a tracer gas. Simulations were then run on portions of the POLAR SEA where the data should be similar to the PIR because of the compartment configurations chosen.

LIMITATIONS OF THE ANALYSIS

The smoke movement analysis was limited by the state of computer models. None of the present models, including the BRI model used, fully incorporate ventilation ducting. Additionally, none of the models have been validated against multi-level structures. Experimentation with smoke movement has also been limited. Experimental work performed to date has been with cold smoke movement while the BRI model addresses smoke movement close to the fire. There are also peculiarities within each computer model. As it was shown with the POLAR SEA berthing area fire, unreasonable and unsatisfactory results may be obtained until the models become able to handle more complicated geometry.

FINDINGS OF THE ANALYSIS

Despite the limitations cited above, the BRI model analysis provided some valuable information. First it supported qualitatively the smoke movement results obtained from the experimental SF_6 tracer gas work conducted on CGC VIGOROUS. However, no direct comparison could be made because of the cold smoke premise using SF_6 and the two-layer hot smoke zone model of the BRI model. The results also indicated that a heavy fuel load compartment such as the paint locker would be self-extinguishing because of rapidly diminished oxygen levels. However, a lighter fuel load in the same paint locker continued to burn, thus generating additional smoke. Another important finding is the rapidity at which smoke moves. A common shipboard arrangement was used to illustrate this case. One compartment located over another with an open hatch between the two served as the scenario. A fire was started in the lower compartment. Within 12 seconds most of the smoke passed into the upper compartment. Within 30 seconds the upper compartment was completely filled with smoke and by 60 seconds both compartments were completely filled.

APPLICATION TO THE PIR

The findings from the smoke movement analysis provide insight that can be applied to the PIR. The rapidity at which the smoke travels vertically indicates that access to hatches must be controlled quickly. Doors leading to stair towers should be the automatic self-closing type. Compartments with heavy fuel loads should have dampers that can be closed remotely possibly from the bridge or ECC when fire is detected.

One technique that could be applied to the PIR is pressurization of escape routes. It was shown in this analysis and the experimental work with SF_6 that smoke will follow air transfer patterns. If the ventilation system can create a greater pressure than a fire creates, the smoke's movement can be controlled. The design of the PIR provides several areas where minor modifications can incorporate this theory. The two berthing areas located on the second deck are ideally designed for this application. The supply systems service the berthing areas and the exhaust systems are located in the heads. Pressure balancing is done through the door louvers which exhaust into the passageway. If a fire occurred in one of the berthing spaces, smoke would flow out into the passageway as well as into the heads. If a supplementary ventilation system was installed in the passageways, to be activated in times of fire, that could create a higher pressure than that created by the fire, smoke could be confined to the space of origin and directed out the exhaust system located in the adjoining head. This would allow a smoke-free escape route for personnel and a clear path for the fire party to follow when combating the fire.

Specifically, the passageways under discussion are 2-100-5-L and the unlabeled corresponding passageway on the port side of the vessel. In the aft berthing area, the passageways are 2-271-1-L and 2-271-0-L. These four passageways surround high density and heavy occupancy areas. The passageways are well suited for pressurization. They are limited access, small in area, easily controlled and relatively simple in geometry.

It has been found that the overpressure of a fire ranges from 0.10 inches of water for an open door compartment to 0.25 inches of water for a closed door compartment. Preliminary findings from work done on the CGC VIGOROUS showed that pressures created by its present ventilation system exceeded 0.25 inches of water across several boundaries. This indicates that ventilation systems designed for the PIR should be adequate to create the required pressures.

RECOMMENDATIONS

It is recommended that the ventilation systems be modified to install additional supply lines to the passageways named above. The additional supply lines would be activated in the case of fire to one of the adjoining berthing areas. Alternatively, the

passageway exhaust system could be designed to reverse the fans and provide positive pressurization. After an evaluation period, it should be determined if other high density heavy occupancy areas should be modified.

9.0 CONCLUSIONS

The design of the PIR has five levels of fire protection as shown in Figure 9.1. The design and "standard practice" adequately address Prevention and First Aid. Passive Fire Protection is generally quite good on the PIR and is the most significant factor in meeting the fire safety objectives. The major improvement recommended for passive fire protection is to subdivide the boiler room. Refinements are recommended for Active Fire Protection systems but the most significant recommendation is for improved and integrated automatic fire detection. The automated and manual fire protection bring the fire safety of every compartment well within the fire safety objectives established.

The Ship Fire Safety Engineering Method proved to be an effective method for integrating the five levels of fire protection. It guided the analysis so that all factors were considered in proportion to their importance to the fire safety objectives. Using the method demonstrated the need for improvements. The most notable of these was the development of a smoke movement analysis methodology which can be integrated with the method.

Just as a ship is designed to meet mission objectives, so should its fire protection be designed to meet specific fire safety objectives. This first attempt to establish compartment-by-compartment fire safety objectives was useful. It permitted the analysis to proceed towards a goal and it demonstrated the need for improved methods for establishing these objectives.

In developing the background for this analysis an extensive data base was developed and information entered which will greatly facilitate future ship fire safety analyses. Information on the frequency of fires, compartment fuel loadings, heat release rates, barrier materials, automated fire extinguishing systems, manual fire fighting, and typical compartment fire scenarios was developed and input. Future fire safety analyses can add to and refine this information but a major portion of the work has been done.

Appendix N, located in Volume III, presents the output of data which should be especially useful to damage control operations. All factors relevant to the fire safety of each compartment are summarized on a single page and the information on all barriers enclosing each compartment on another. (Examples of these summaries can be seen on pages 7-53 and 7-54). The data base could be updated for the "as built" PIR and then these summaries could be maintained in Damage Control Central as reference for pre-fire planning and fire fighting operations. The summaries can be modified to include any significant information.

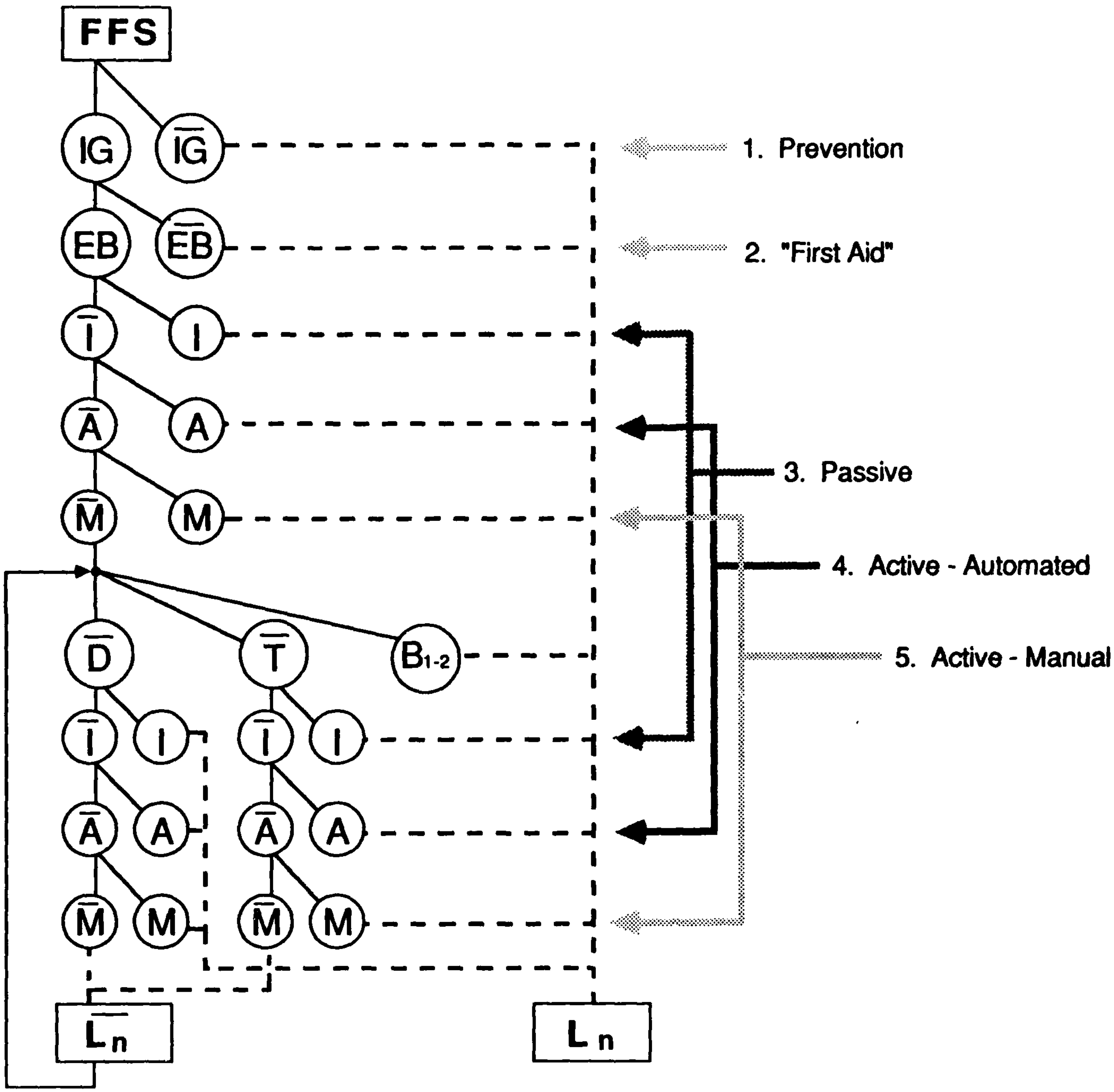

FIGURE 9.1 Levels of Fire Protection on PIR

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